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Report No. ARL 88-2

THE EFFECTS OF BLAST TRAUMA (IMPULSE NOISE) ON HEARING: A PARAMETRIC STUDY

ANNUAL REPORT

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ROBERT I. DAVIS
GEORGE A. TURRENTINE

JULY 22, 1988

Supported by

U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701-5012

Contract No. DAMD17-86-C-6172

The Research Foundation of the
State University of New York
Albany, NY 12201-0009

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AD______________

State University of New York at Plattsburgh
Auditory Research Laboratories

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FOREWORD

Disclaimer

Citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

Animal Use

In conducting the research described in this report, the investigators adhered to the "Guide for the Care and use of Laboratory Animals," prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council (DHHS Publication No. (NIH) 86-23, revised 1985).

__Statement of Progress__: During the first year of this contract our primary goal was to obtain hearing threshold data, tuning curves and histological data on chinchillas that were exposed under a variety of conditions to low frequency energy-content blast waves. The source of these blast waves was a modified 6" x 6" cross section shock tube which terminated in an exponential horn. A minimum of five animals constituted an experimental group. The experimental groups that were to be run are detailed in the table. Twenty-one groups of animals constituted this phase of the project. Thirteen of the 21 groups had been completed while the principal investigator was at the University of Texas at Dallas. The remaining eight groups have been completed as are indicated in the table below. [The groups complete in Texas are indicated by asterisks under the symbol for sample size (N)].

Table of Experimental Groups

Group	N	Intensity	Number	Rate
1	*	150 dB Peak SPL	1	
2	5	150 dB Peak SPL	10	10 per minute
3	*	150 dB Peak SPL	10	1 per minute
4	5	150 dB Peak SPL	10	1 per 10 minutes
5	5	150 dB Peak SPL	100	10 per minute
6	*	150 dB Peak SPL	100	1 per minute
7	5	150 dB Peak SPL	100	1 per 10 minutes
8	*	155 dB Peak SPL	1	
9	*	155 dB Peak SPL	10	10 per minute
10	*	155 dB Peak SPL	10	1 per minute
11	*	155 dB Peak SPL	10	1 per 10 minutes
12	*	155 dB Peak SPL	100	10 per minute
13	*	155 dB Peak SPL	100	1 per minute
14	*	155 dB Peak SPL	100	1 per 10 minutes
15	*	160 dB Peak SPL	1	
16	5	160 dB Peak SPL	10	10 per minute
17	*	160 dB Peak SPL	10	1 per minute
18	5	160 dB Peak SPL	10	1 per 10 minutes
19	5	160 dB Peak SPL	100	10 per minute
20	*	160 dB Peak SPL	100	1 per minute
21	5	160 dB Peak SPL	100	1 per 10 minutes
Total	40			

* Group completed while the principal investigator was at the University of Texas at Dallas.

Appendix I contains the raw data and summary statistics for these eight groups. The shock tube produced a blast wave that had the bulk of its energy in the octave band centered at 125 Hz. The data set for each exposed animal consisted of preexposure measures of hearing, recovery threshold measures, permanent threshold shift (PTS) measures and histology. Three preexposure audiometric thresholds were measured at 0.5, 1.0, 2.0, 4.0, 8.0, 11.2, and 16.0 kHz. Postexposure recovery functions were measured on each animal at postexposure times of t = 0, 2, 8, 24, and 240 hours at test frequencies of 0.5, 2.0 and 8.0 kHz. At 30 days postexposure three final audiograms were collected on each animal at each of the audiometric test

frequencies to establish each animals PTS. In addition, tuning curves were collected for each animal at probe frequencies of 0.5, 1.0, 2.0, 4.0, 8.0 and 11.2 kHz prior to exposure and at 30 days postexposure. After the thirty-day testing was complete, each animal was sacrificed by decapitation and the cochlea was examined using the surface preparation histology procedure which yields a quantitative analysis of the sensory cell population in the cochlea.

A detailed analysis and interpretation of the data is presented in the summary report which comprises Appendix II.

Appendix I

Individual and Group Statistics from:

The Effects of Blast Trauma (Impulse Noise) on Hearing: A Parametric Study

Summary Data for the Group Exposed to:

150 dB, 10X, 10/M

Animal #		
0510	-	Completed the Entire Protocol
0511	-	Completed the Entire Protocol
0512	-	Completed the Entire Protocol
0513	-	Completed the Entire Protocol
0524	-	Completed the Entire Protocol

150 dB 10X 10/M

PRE-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0510	19.2	5.8	17.5	7.5	17.5	17.5	22.5
0511	19.2	2.5	15.8	0.8	20.8	22.5	25.8
0512	22.5	9.2	10.8	2.5	17.5	19.2	29.2
0513	22.5	14.2	22.5	9.2	22.5	15.8	20.8
0524	22.5	4.2	14.2	4.2	17.5	12.5	34.2
Mean	21.2	7.2	16.2	4.8	19.2	17.5	26.5
S.D.	1.8	4.6	4.3	3.5	2.4	3.7	5.3

POST-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0510	19.2	2.5	12.5	4.2	17.5	17.5	25.8
0511	17.5	2.5	18.7	0.8	27.5	22.5	29.2
0512	17.5	17.5	14.2	2.5	24.2	17.5	22.5
0513	25.8	14.2	15.8	10.8	22.5	15.8	20.8
0524	22.5	10.8	19.2	12.5	27.5	19.2	52.5
Mean	20.5	9.5	16.1	6.2	23.8	18.5	30.2
S.D.	3.6	6.8	2.9	5.2	4.2	2.5	12.9

PERMANENT THRESHOLD SHIFT (dB)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0510	0.0	-3.3	-5.0	-3.3	0.0	0.0	3.3
0511	-1.7	0.0	2.9	0.0	6.7	0.0	3.3
0512	-5.0	8.3	3.3	0.0	6.7	-1.7	-6.7
0513	3.3	0.0	-6.7	1.7	0.0	0.0	0.0
0524	0.0	6.7	5.0	8.3	10.0	6.7	18.3
Mean	-0.7	2.3	-0.1	1.3	4.7	1.0	3.7
S.D.	3.0	4.9	5.3	4.3	4.5	3.3	9.2

150 dB 10X 10/M

TEMPORARY THRESHOLD SHIFT (dB)

Frequency 0.5 kHz

Animal\Hr	0	2	8	24	240	Max
0510	3.3	3.3	-1.7	-1.7	-1.7	3.3
0511	3.3	-1.7	-1.7	-1.7	-1.7	3.3
0512	20.0	30.0	5.0	0.0	0.0	30.0
0513	5.0	0.0	0.0	0.0	-5.0	5.0
0524	0.0	20.0	15.0	10.0	10.0	20.0
Mean	6.3	10.3	3.3	1.3	0.3	12.3
S.D.	7.8	14.0	7.1	4.9	5.7	12.1

Frequency 2.0 kHz

Animal\Hr	0	2	8	24	240	Max
0510	5.0	0.0	-5.0	0.0	-5.0	5.0
0511	-8.3	-8.3	1.7	-3.3	-8.3	1.7
0512	51.7	56.7	21.7	16.7	6.7	56.7
0513	0.0	-5.0	-5.0	-5.0	-5.0	0.0
0524	13.3	13.3	13.3	8.3	8.3	13.3
Mean	12.3	11.3	5.3	3.3	-0.7	15.3
S.D.	23.4	26.6	11.8	9.1	7.6	23.7

Frequency 8.0 kHz

Animal\Hr	0	2	8	24	240	Max
0510	5.0	-5.0	0.0	0.0	5.0	5.0
0511	-8.3	-3.3	1.7	-8.3	-8.3	1.7
0512	15.0	25.0	10.0	5.0	5.0	25.0
0513	5.0	-5.0	-5.0	0.0	-5.0	5.0
0524	15.0	25.0	15.0	15.0	15.0	25.0
Mean	6.3	7.3	4.3	2.3	2.3	12.3
S.D.	9.6	16.1	8.1	8.6	9.3	11.6

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 10/M

Probe Frequency: 0.5 kHz

Masker (kHz):		0.150	0.200	0.300	0.400	0.520	0.600	0.650	0.750	1.300	2.200
Animal	(Q-10 dB)					Pre-Exposure					
0510	(1.66)	67.5	67.5	57.5	52.5	37.5	42.5	42.5	47.5	95.0*	95.0*
0511	(1.35)	72.5	62.5	57.5	42.5	37.5	42.5	37.5	47.5	62.5	82.5
0512	(1.49)	72.5	62.5	57.5	47.5	37.5	37.5	37.5	47.5	82.5	95.0*
0513	(2.12)	67.5	57.5	47.5	32.5	42.5	47.5	52.5	52.5	87.5	92.5
0524	(1.49)	72.5	62.5	57.5	52.5	42.5	47.5	47.5	52.5	72.5	95.5
Mean	(1.62)	70.5	62.5	55.5	45.5	39.5	43.5	43.5	49.5	80.0	92.1
S.D.	(0.30)	2.7	3.5	4.5	8.4	2.7	4.2	6.5	2.7	12.7	5.5
Animal	(Q-10 dB)					Post-Exposure					
0510	(1.35)	72.5	67.5	57.5	42.5	37.5	37.5	42.5	47.5	97.5	95.0*
0511	(0.87)	67.5	62.5	47.5	42.5	37.5	37.5	42.5	42.5	57.5	77.5
0512	(3.19)	72.5	62.5	57.5	42.5	27.5	37.5	37.5	42.5	97.5	95.0*
0513	(3.08)	72.5	62.5	57.5	52.5	47.5	37.5	37.5	52.5	77.5	87.5
0524	(1.04)	62.5	62.5	52.5	47.5	37.5	42.5	37.5	42.5	57.5	95.0*
Mean	(1.90)	69.5	63.5	54.5	45.5	37.5	38.5	39.5	45.5	77.5	90.0
S.D.	(1.14)	4.5	2.2	4.5	4.5	7.1	2.2	2.7	4.5	20.0	7.7

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 10/M

Probe Frequency: 1.0 kHz

Masker (kHz):		0.150	0.200	0.400	0.550	0.800	1.050	1.300	1.700	1.900	2.500
Animal	(Q-10 dB)					Pre-Exposure					
0510	(4.63)	77.5	92.5	47.5	47.5	52.5	27.5	47.5	77.5	87.5	91.0*
0511	(2.47)	82.5	72.5	62.5	57.5	47.5	32.5	42.5	57.5	72.5	91.0*
0512	(1.66)	77.5	67.5	62.5	52.5	32.5	27.5	32.5	62.5	77.5	91.0*
0513	(2.10)	77.5	72.5	62.5	57.5	42.5	32.5	42.5	57.5	82.5	91.0*
0524	(1.08)	77.5	67.5	62.5	52.5	32.5	27.5	32.5	37.5	47.5	82.5
Mean	(2.39)	78.5	74.5	59.5	53.5	41.5	29.5	39.5	58.5	73.5	89.3
S.D.	(1.35)	2.2	10.4	6.7	4.2	8.9	2.7	6.7	14.3	15.6	3.8
Animal	(Q-10 dB)					Post-Exposure					
0510	(3.13)	77.5	72.5	62.5	52.5	37.5	22.5	37.5	62.5	77.5	91.0*
0511	(1.66)	72.5	67.5	57.5	47.5	27.5	22.5	27.5	57.5	62.5	77.5
0512	(4.53)	77.5	72.5	62.5	52.5	47.5	32.5	72.5	92.5	91.0*	91.0*
0513	(3.58)	77.5	72.5	57.5	52.5	37.5	22.5	42.5	52.5	67.5	87.5
0524	(2.08)	77.5	72.5	57.5	52.5	47.5	27.5	27.5	57.5	87.5	91.0*
Mean	(3.00)	76.5	71.5	59.5	51.5	39.5	25.5	41.5	64.5	77.2	87.6
S.D.	(1.15)	2.2	2.2	2.7	2.2	8.4	4.5	18.5	16.0	12.3	5.8

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 10/M

Probe Frequency: 2.0 kHz

Masker (kHz):		0.300	0.750	0.900	1.300	1.700	2.050	2.200	3.000	3.500	4.000
Animal	(Q-10 dB)					Pre-Exposure					
0510	(3.20)	77.5	57.5	47.5	52.5	42.5	32.5	37.5	62.5	77.5	96.0*
0511	(1.45)	77.5	57.5	57.5	52.5	42.5	42.5	37.5	47.5	52.5	96.0*
0512	(2.70)	82.5	57.5	47.5	37.5	37.5	22.5	22.5	42.5	72.5	96.0*
0513	(4.09)	97.5	77.5	72.5	57.5	42.5	32.5	42.5	47.5	62.5	92.5
0524	(1.89)	77.5	57.5	47.5	27.5	17.5	17.5	27.5	42.5	62.5	77.5
Mean	(2.67)	82.5	61.5	54.5	45.5	36.5	29.5	33.5	48.5	65.5	91.6
S.D.	(1.05)	8.7	8.9	11.0	12.5	10.8	9.7	8.2	8.2	9.7	8.0
Animal	(Q-10 dB)					Post-Exposure					
0510	(1.62)	72.5	52.5	42.5	42.5	37.5	32.5	32.5	52.5	67.5	96.0*
0511	(5.24)	67.5	52.5	42.5	52.5	47.5	32.5	42.5	47.5	72.5	92.5
0512	(2.62)	72.5	57.5	47.5	37.5	42.5	32.5	27.5	42.5	57.5	96.0*
0513	(7.89)	72.5	67.5	52.5	57.5	47.5	37.5	22.5	62.5	82.5	96.0*
0524	(2.29)	72.5	52.5	52.5	52.5	47.5	32.5	32.5	47.5	72.5	96.0*
Mean	(3.93)	71.5	56.5	47.5	48.5	44.5	33.5	31.5	50.5	70.5	95.3
S.D.	(2.60)	2.2	6.5	5.0	8.2	4.5	2.2	7.4	7.6	9.1	1.6

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 10/M

Probe Frequency: 4.0 kHz

Masker (kHz):		0.450	1.300	2.200	3.000	3.500	4.100	4.500	5.000	5.600	6.000
Animal	(Q-10 dB)					Pre-Exposure					
0510	(4.10)	77.5	67.5	62.5	62.5	32.5	22.5	32.5	52.5	82.5	92.0*
0511	(2.98)	87.5	62.5	62.5	52.5	32.5	27.5	32.5	42.5	62.5	77.5
0512	(3.77)	77.5	57.5	52.5	57.5	27.5	22.5	32.5	42.5	57.5	92.0*
0513	(3.26)	77.5	52.5	52.5	42.5	32.5	27.5	37.5	57.5	82.5	92.0*
0524	(4.10)	77.5	57.5	52.5	42.5	27.5	17.5	27.5	37.5	57.5	82.5
Mean	(3.64)	79.5	61.5	56.5	51.5	30.5	23.5	32.5	46.5	68.5	87.2
S.D.	(0.51)	4.5	4.2	5.5	8.9	2.7	4.2	3.5	8.2	12.9	6.8
Animal	(Q-10 dB)					Post-Exposure					
0510	(5.06)	72.5	62.5	52.5	57.5	32.5	17.5	27.5	52.5	67.5	82.5
0511	(3.17)	77.5	52.5	52.5	47.5	27.5	22.5	27.5	42.5	47.5	67.5
0512	(3.71)	67.5	57.5	52.5	47.5	22.5	17.5	27.5	52.5	52.5	72.5
0513	(3.62)	77.5	67.5	52.5	47.5	27.5	22.5	32.5	57.5	77.5	87.5
0524	(3.17)	77.5	62.5	57.5	47.5	27.5	22.5	27.5	42.5	62.5	87.5
Mean	(3.75)	74.5	60.5	53.5	49.5	27.5	20.5	28.5	49.5	61.5	79.5
S.D.	(0.78)	4.5	5.7	2.2	4.5	3.5	2.7	2.2	6.7	11.9	9.1

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 10/M

Probe Frequency: 8.0 kHz

Masker (kHz):		0.450	1.300	2.500	5.900	7.000	8.100	9.300	11.000	12.700	14.000
Animal	(Q-10 dB)					Pre-Exposure					
0510	(3.88)	82.5	72.5	62.5	42.5	47.5	27.5	32.5	57.5	100.0*	95.0*
0511	(1.84)	82.5	72.5	52.5	47.5	37.5	37.5	42.5	62.5	87.5	92.5
0512	(3.52)	82.5	62.5	57.5	37.5	42.5	32.5	42.5	77.5	100.0*	95.0*
0513	(1.80)	82.5	72.5	57.5	47.5	42.5	37.5	37.5	52.5	100.0*	95.0*
0524	(1.67)	77.5	62.5	57.5	47.5	37.5	32.5	32.5	37.5	67.5	82.5
Mean	(2.54)	81.5	68.5	57.5	44.5	41.5	33.5	37.5	57.5	91.0	92.0
S.D.	(1.07)	2.2	5.5	3.5	4.5	4.2	4.2	5.0	14.6	14.2	5.4
Animal	(Q-10 dB)					Post-Exposure					
0510	(5.99)	82.5	67.5	77.5	42.5	47.5	27.5	42.5	77.5	100.0*	95.0*
0511	(3.72)	87.5	62.5	62.5	42.5	52.5	37.5	42.5	77.5	100.0*	87.5
0512	(6.13)	77.5	62.5	62.5	47.5	47.5	37.5	27.5	77.5	100.0*	92.5
0513	(3.88)	77.5	67.5	57.5	47.5	52.5	32.5	37.5	62.5	97.5	95.0*
0524	(3.51)	82.5	62.5	62.5	57.5	57.5	37.5	42.5	57.5	82.5	95.0*
Mean	(4.65)	81.5	64.5	64.5	47.5	51.5	34.5	38.5	70.5	96.0	93.0
S.D.	(1.30)	4.2	2.7	7.6	6.1	4.2	4.5	6.5	9.7	7.6	3.3

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 10/M

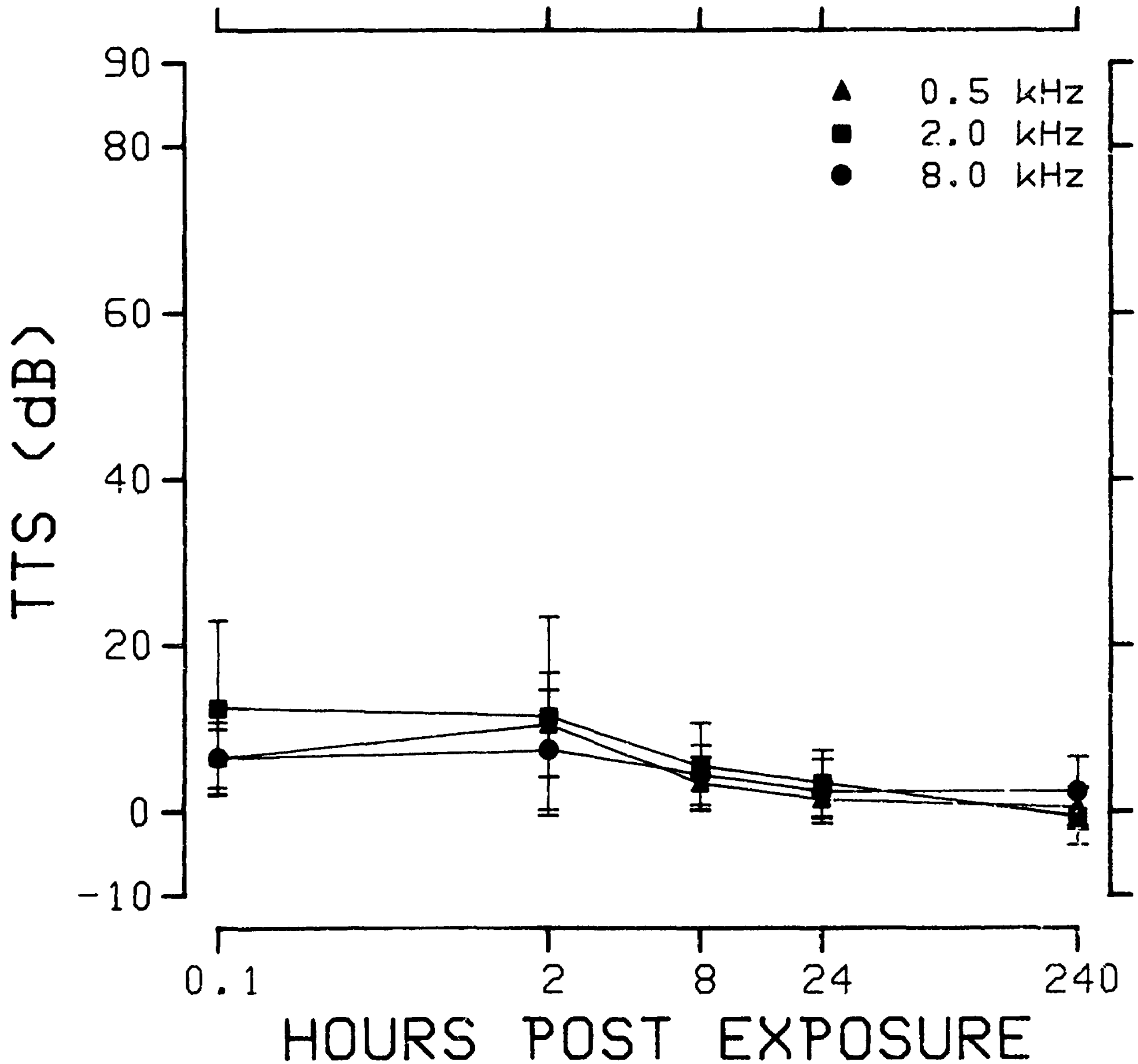
Probe Frequency: 11.2 kHz

Masker (kHz):		1.000	4.000	7.000	9.000	11.000	11.500	12.000	13.000	14.500	16.000
Animal	(Q-10 dB)					Pre-Exposure					
0510	(4.53)	72.5	62.5	67.5	57.5	37.5	32.5	37.5	42.5	72.5	82.5
0511	(15.37)	77.5	67.5	67.5	52.5	42.5	32.5	52.5	57.5	67.5	91.0*
0512	(8.00)	62.5	52.5	57.5	47.5	37.5	37.5	27.5	37.5	62.5	91.0*
0513	(8.94)	77.5	57.5	62.5	57.5	37.5	32.5	52.5	52.5	72.5	87.5
0524	(7.47)	82.5	62.5	57.5	52.5	32.5	27.5	37.5	42.5	62.5	91.0*
Mean	(8.86)	74.5	60.5	62.5	53.5	37.5	32.5	41.5	46.5	67.5	88.6
S.D.	(4.00)	7.6	5.7	5.0	4.2	3.5	3.5	10.8	8.2	5.0	3.7
Animal	(Q-10 dB)					Post-Exposure					
0510	(5.36)	67.5	62.5	62.5	52.5	32.5	37.5	42.5	37.5	57.5	72.5
0511	(11.48)	67.5	57.5	72.5	57.5	52.5	42.5	52.5	57.5	92.5	91.0*
0512	(10.35)	62.5	57.5	62.5	52.5	47.5	32.5	27.5	47.5	62.5	91.0*
0513	(9.32)	67.5	57.5	62.5	57.5	32.5	47.5	42.5	42.5	82.5	91.0*
0524	(3.26)	87.5	77.5	92.5	87.5	72.5	72.5	72.5	82.5	92.5	87.5
Mean	(7.95)	70.5	62.5	70.5	61.5	47.5	46.5	47.5	53.5	77.5	86.6
S.D.	(3.49)	9.7	8.7	13.0	14.7	16.6	15.6	16.6	17.8	16.6	8.0

The Group Mean Recovery Curves

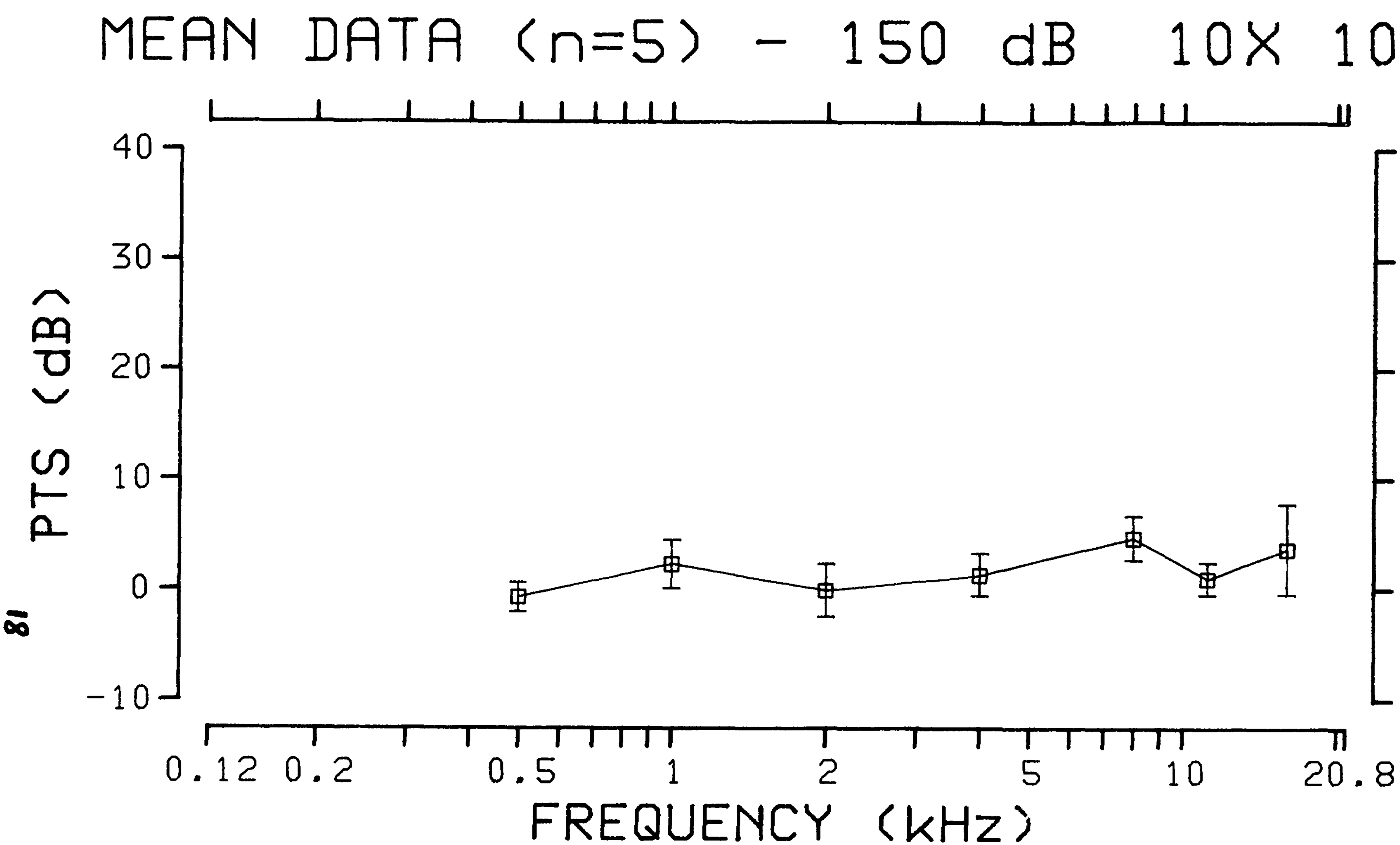
Measured at Three Test Frequencies

MEAN DATA (n=5) - 150 dB 10X 10/M



The Group Mean Permanent Threshold Shift (PTS)

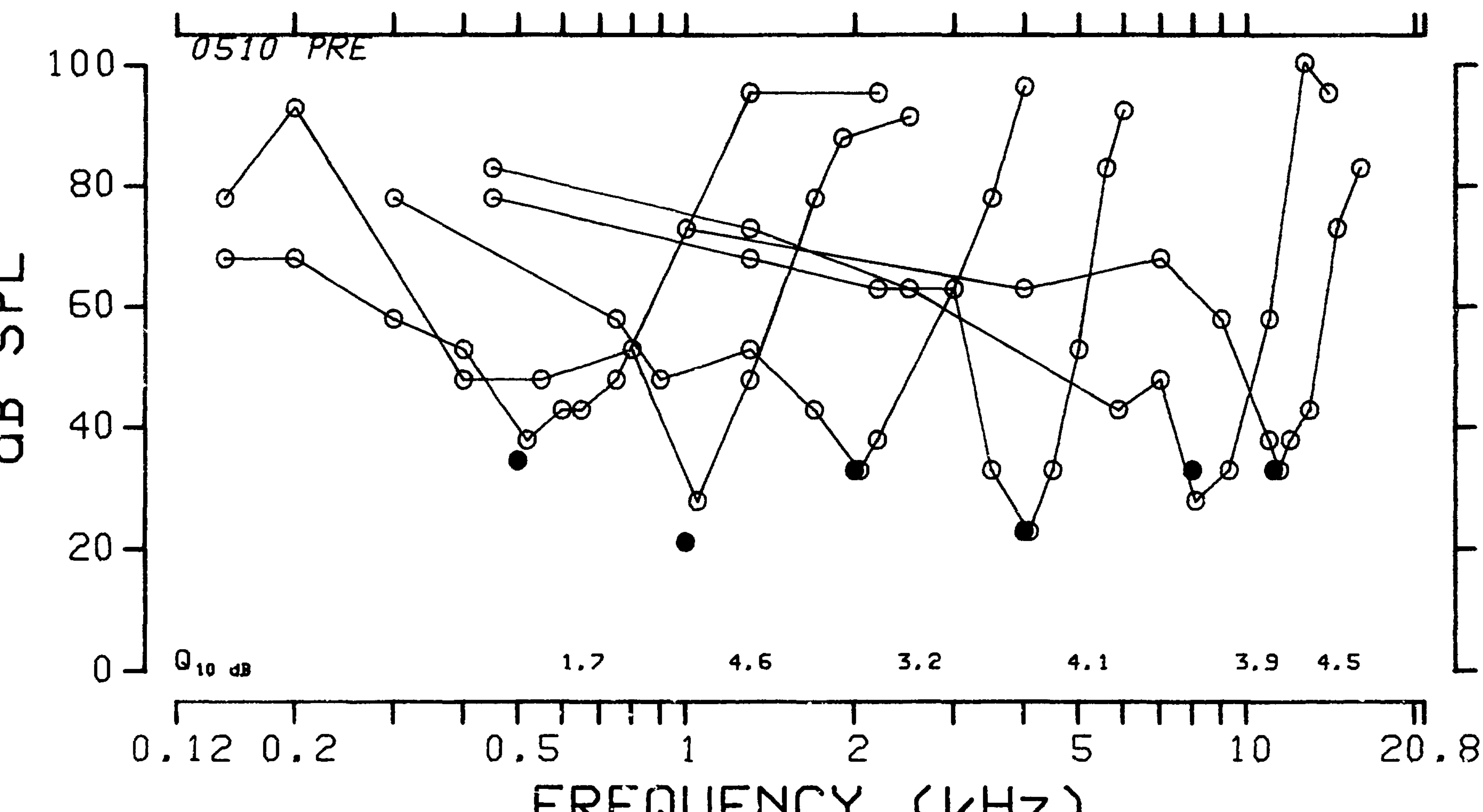
for all Test Frequencies



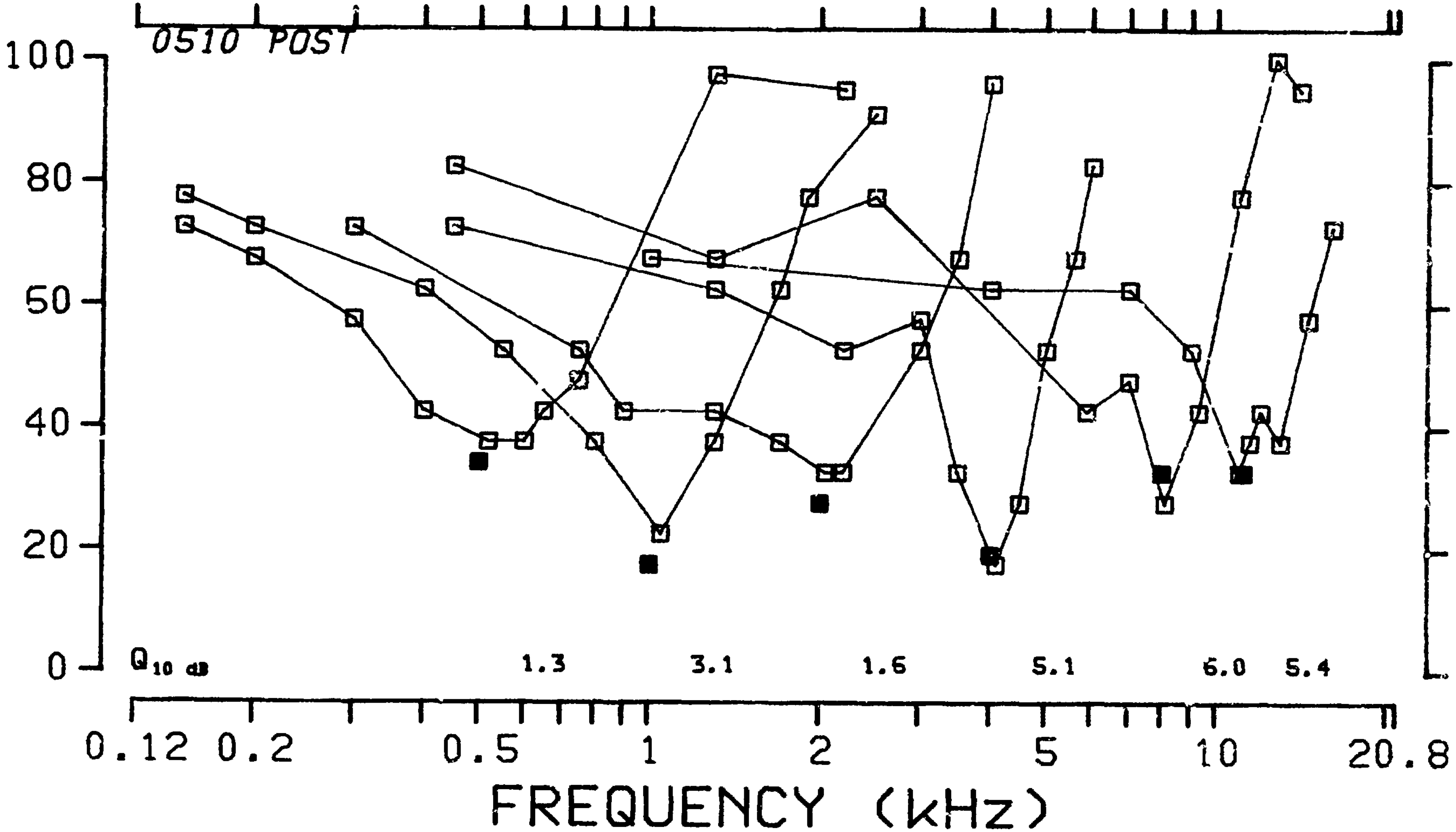
MEAN DATA (n=5) - 150 dB 10X 10/M
PTS (dB)
40
30
20
10
0
-10
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

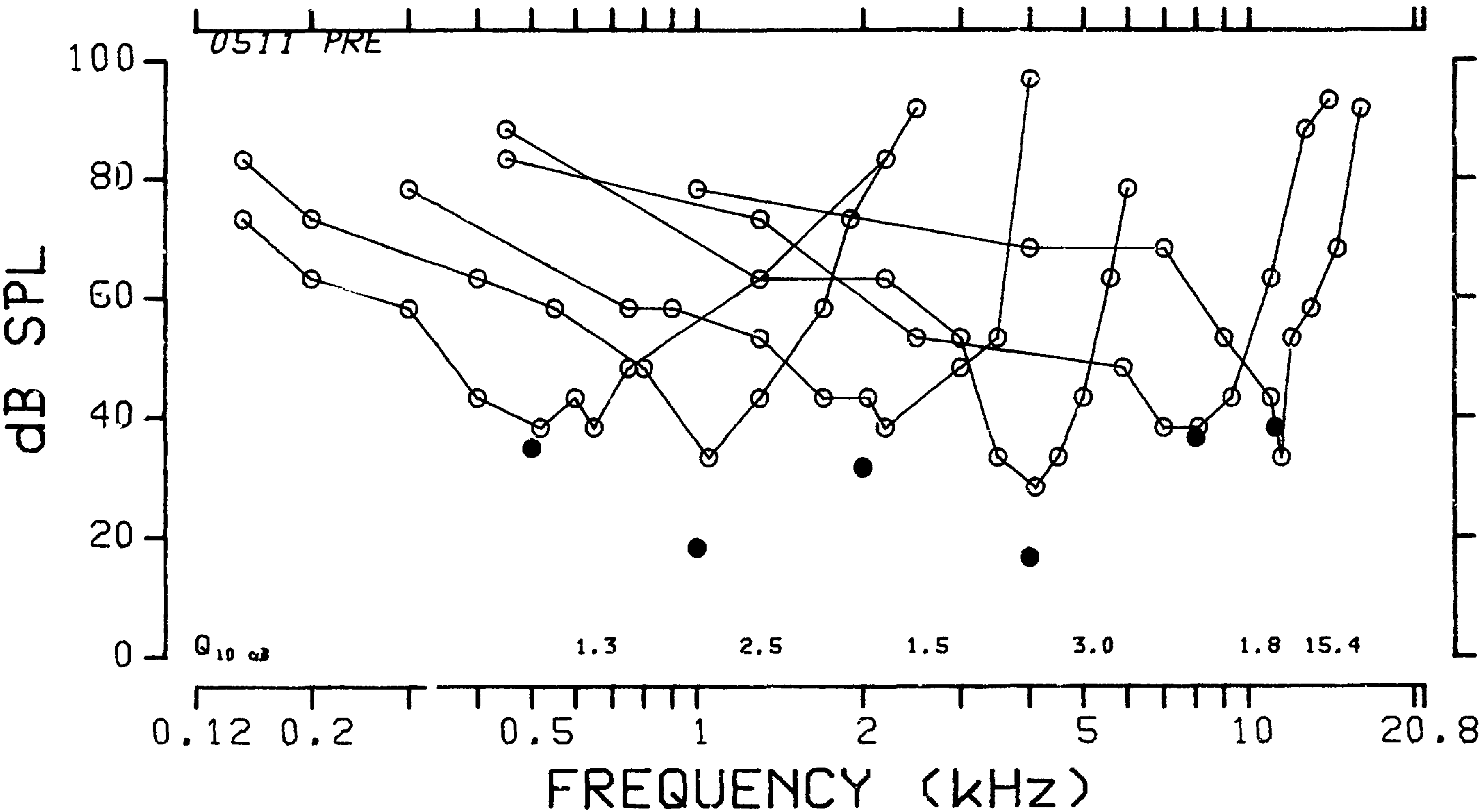
The Pre and Postexposure Tuning Curves for Individual Animals in this Exposure Group.

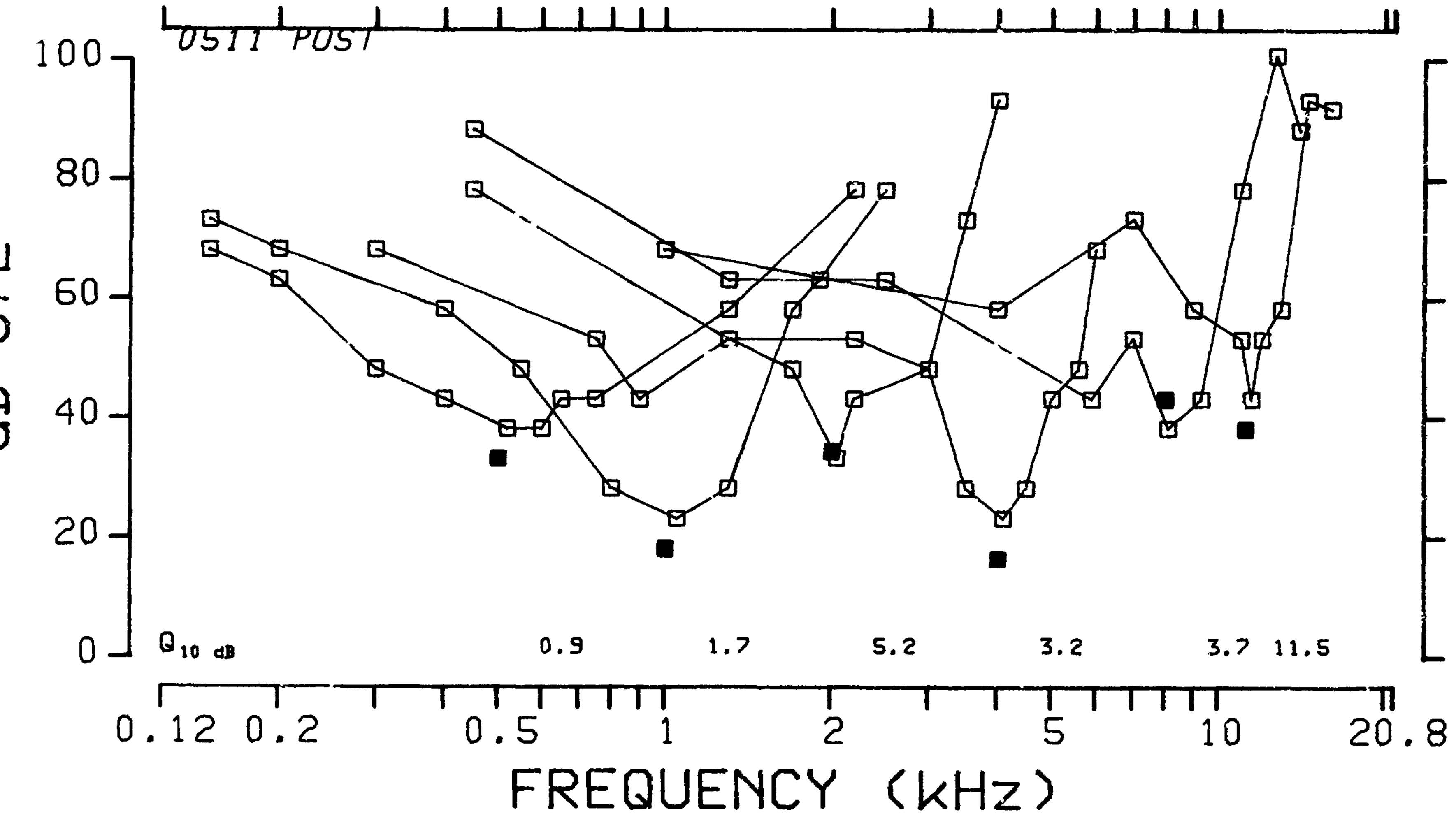
The Solid Symbol represents the intensity of the probe tone.

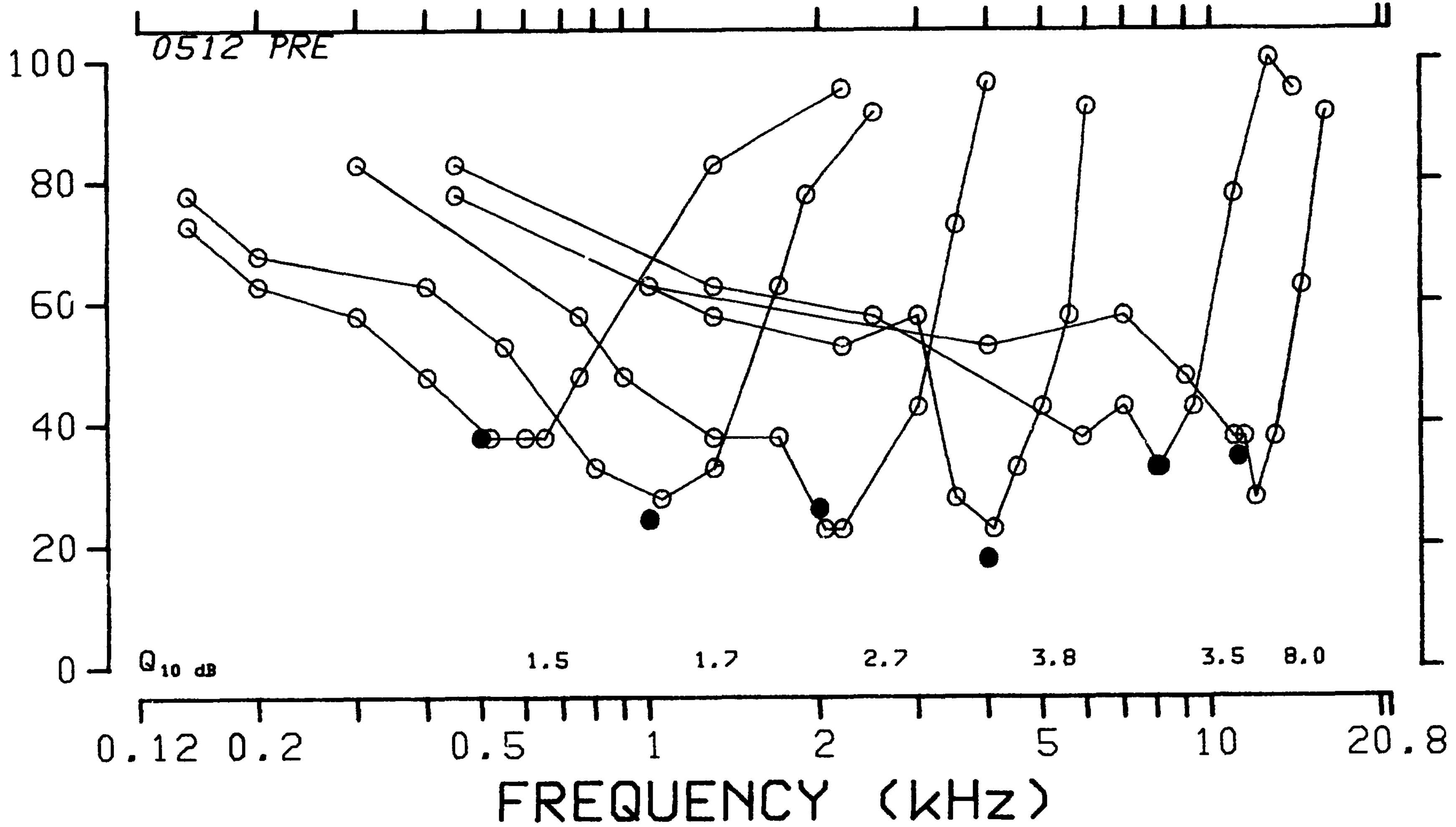


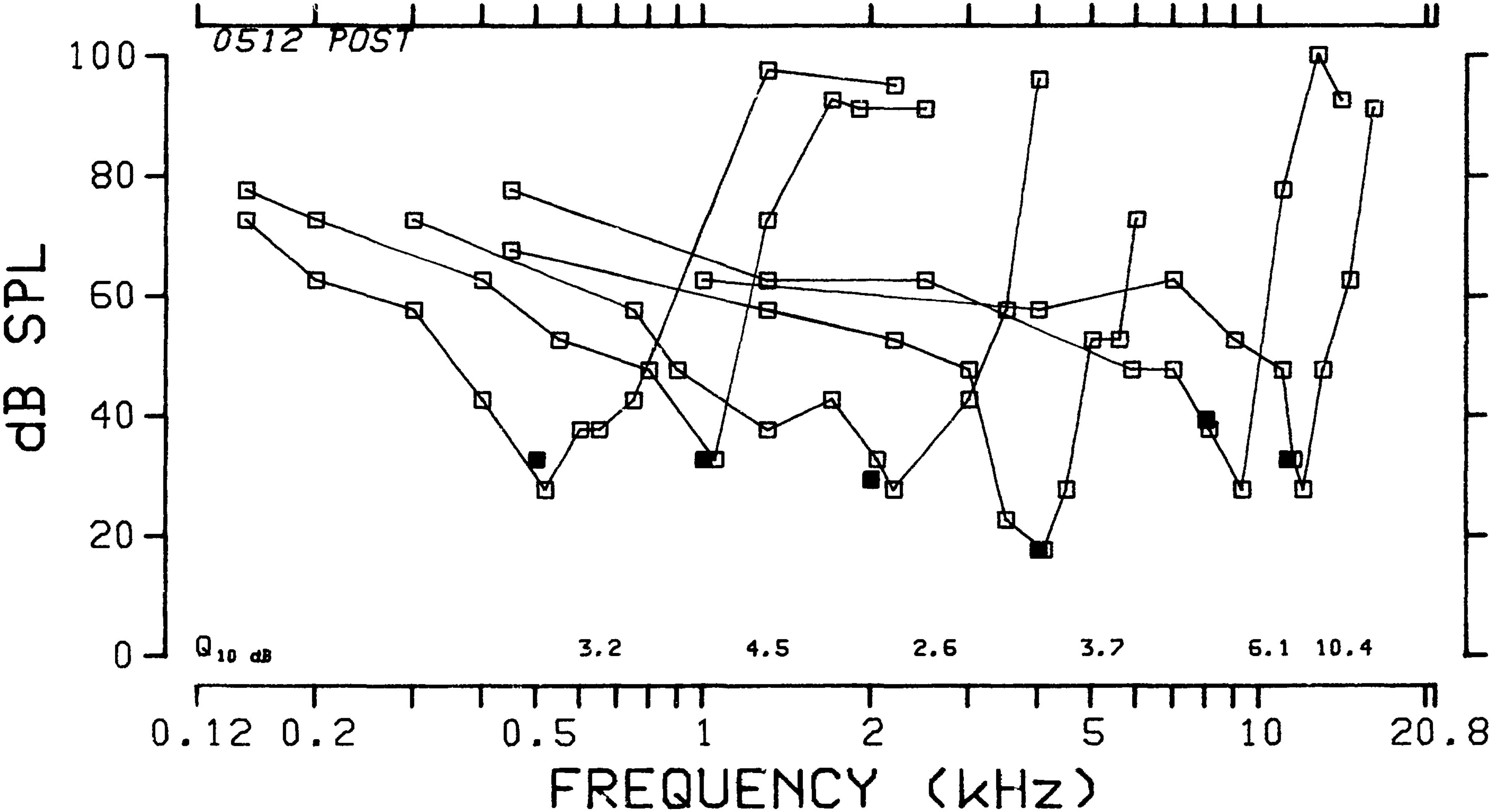
0510 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.7
4.6
3.2
4.1
3.9
4.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

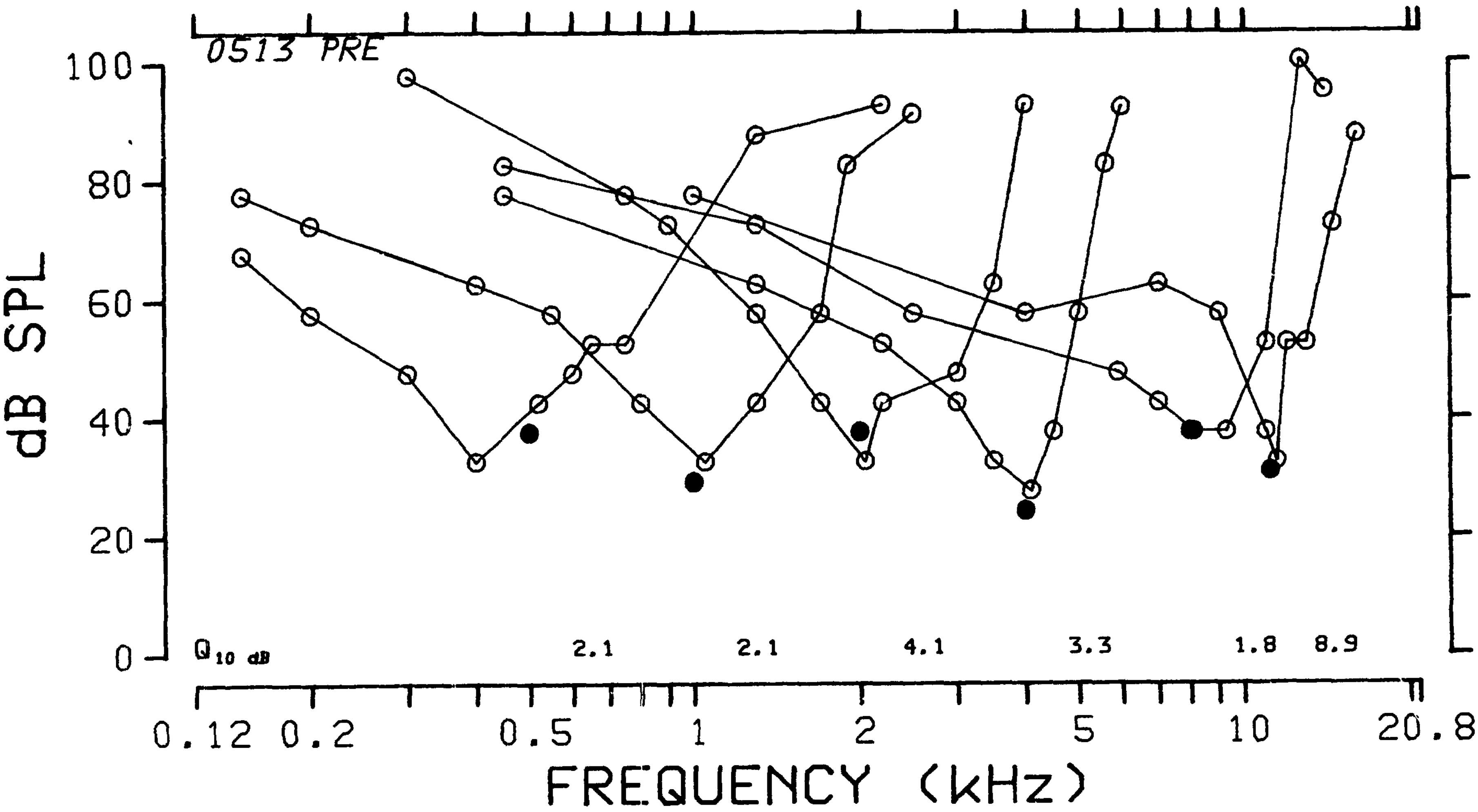

0510 POST
dB SPL
100
80
50
40
20
0
$Q_{10\ dB}$
1.3
3.1
1.6
5.1
6.0
5.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

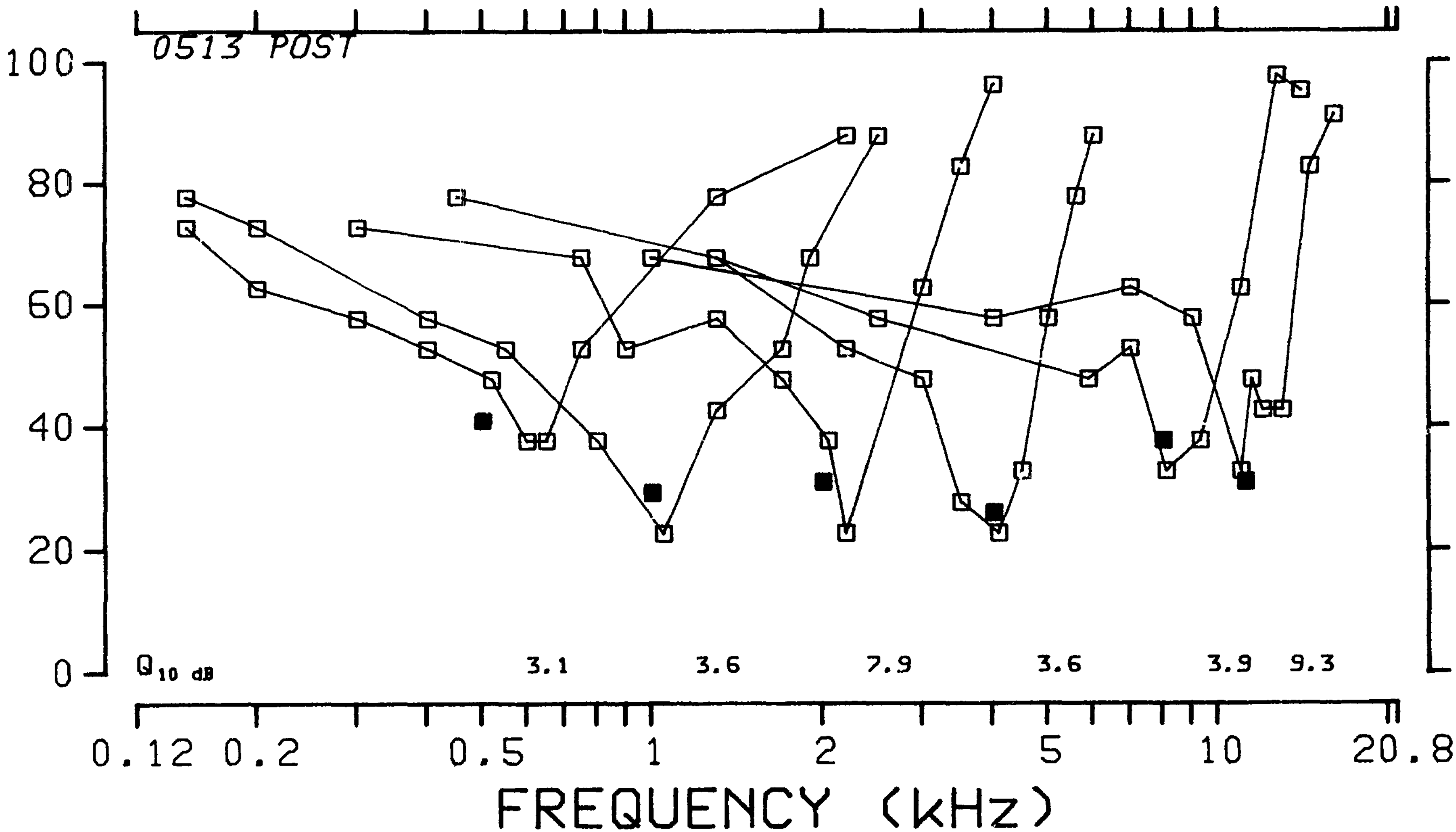

0511 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.3
2.5
1.5
3.0
1.8
15.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

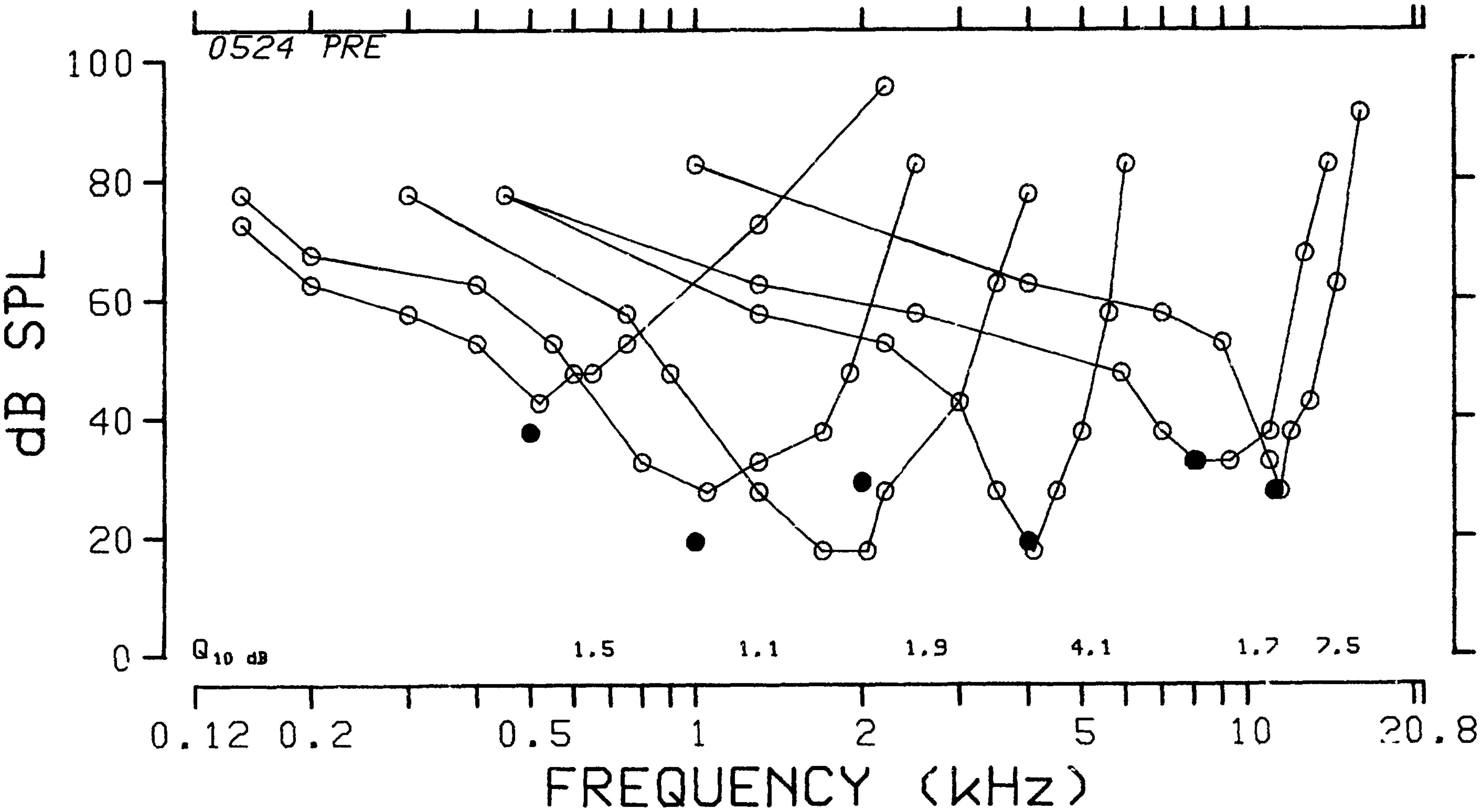

0511 POST
dB SPL
100
80
60
40
20
0
Q10 dB
0.9
1.7
5.2
3.2
3.7
11.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

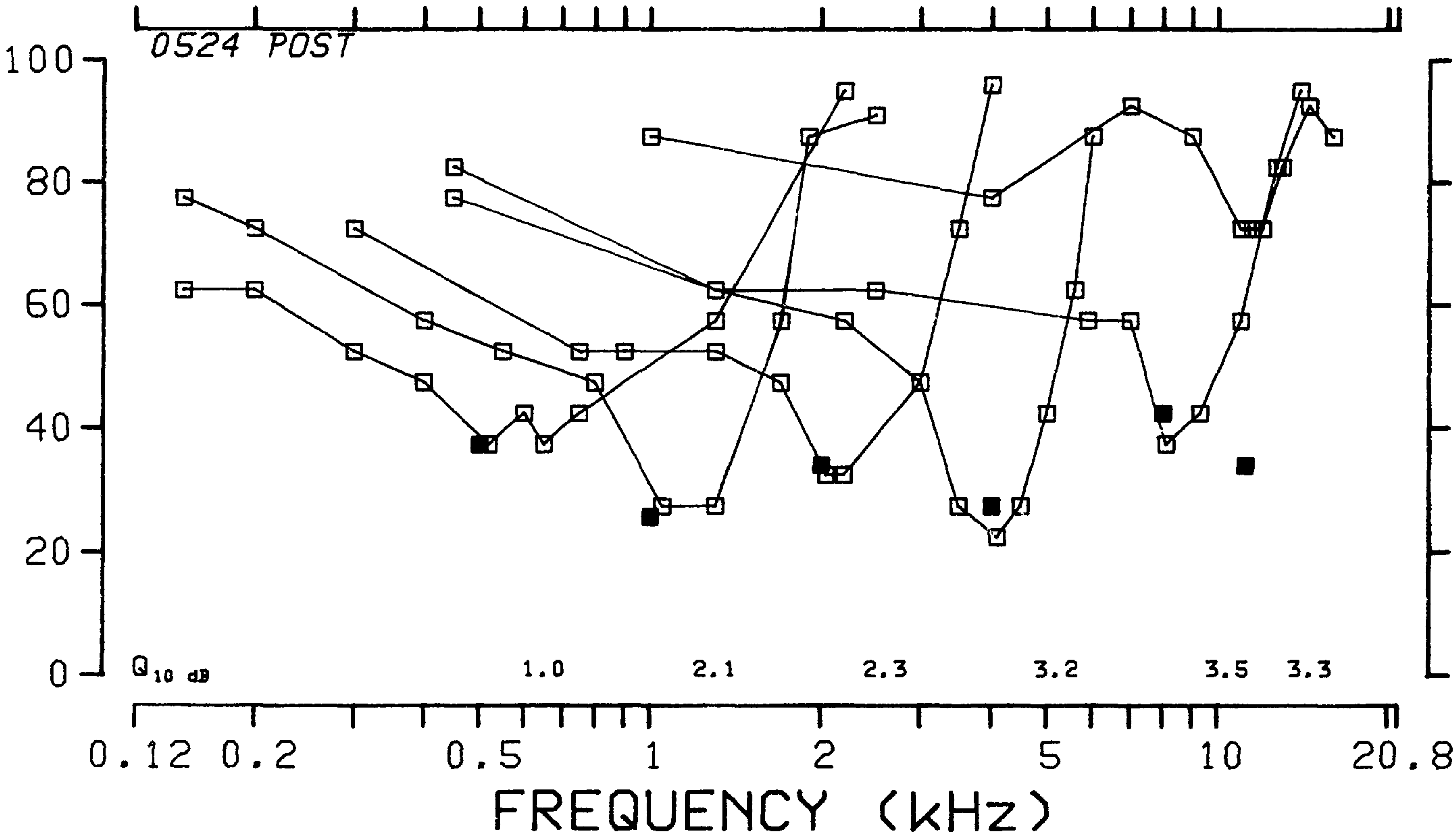

0512 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.5
1.7
2.7
3.8
3.5
8.0
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0512 POST
dB SPL
100
80
60
40
20
0
Q10 dB
3.2
4.5
2.6
3.7
6.1
10.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0513 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
2.1
2.1
4.1
3.3
1.8
8.9
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0513 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
3.1
3.6
7.9
3.6
3.9
9.3
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0524 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.5
1.1
1.9
4.1
1.7
7.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0524 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.0
2.1
2.3
3.2
3.5
3.3
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

150 dB 10X 10/M

TOTAL NUMBER OF COCHLEAR SENSORY CELLS MISSING

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0510	21	24	15	21	60
0511	6	68	137	134	339
0512	4	218	325	64	607
0513	54	74	130	238	442
0524	0	26	39	110	175
GROUP MEAN	17				325
S.D.	22				216
S.E.	10				96

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

	OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	OUTER HAIR CELLS
GROUP MEANS			
	0.125 kHz	2.4	67.2
	0.25 kHz	3.2	49.2
	0.5 kHz	4.4	28.8
	1 kHz	2.2	106.0
	2 kHz	1.2	36.0
	4 kHz	0.4	15.4
	8 kHz	0.4	11.0
	16 kHz	2.8	11.0
STANDARD DEVIATIONS			
	0.125 kHz	3.2	67.5
	0.25 kHz	5.1	43.4
	0.5 kHz	7.2	32.8
	1 kHz	2.5	188.0
	2 kHz	1.8	42.2
	4 kHz	0.9	15.2
	8 kHz	0.5	13.5
	16 kHz	4.8	12.9

150 dB 10X 10/M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0510							
0.125 kHz	2	3	4	14	21	0	0
0.25 kHz	3	5	5	0	10	0	0
0.5 kHz	3	3	0	2	5	0	0
1 kHz	6	5	1	3	9	0	1
2 kHz	4	2	0	1	3	0	0
4 kHz	2	3	1	0	4	0	1
8 kHz	1	1	3	1	5	0	0
16 kHz	0	2	1	0	3	0	0
TOTALS	21	24	15	21	60	0	2
CHINCHILLA 0511							
0.125 kHz	1	52	93	37	182	0	1
0.25 kHz	1	3	32	78	113	0	0
0.5 kHz	2	2	4	6	12	0	0
1 kHz	2	2	0	0	2	0	1
2 kHz	0	4	3	3	10	0	0
4 kHz	0	3	4	4	11	0	0
8 kHz	0	2	1	2	5	0	0
16 kHz	0	0	0	4	4	0	0
TOTALS	6	68	137	134	339	0	2
CHINCHILLA 0512							
0.125 kHz	1	1	4	16	21	0	0
0.25 kHz	0	3	4	11	18	0	0
0.5 kHz	0	5	6	5	16	0	0
1 kHz	0	172	251	17	440	3	3
2 kHz	0	31	50	6	87	0	1
4 kHz	0	2	1	0	3	0	0
8 kHz	0	2	3	2	7	0	0
16 kHz	3	2	6	7	15	0	0
TOTALS	4	218	325	64	607	3	4

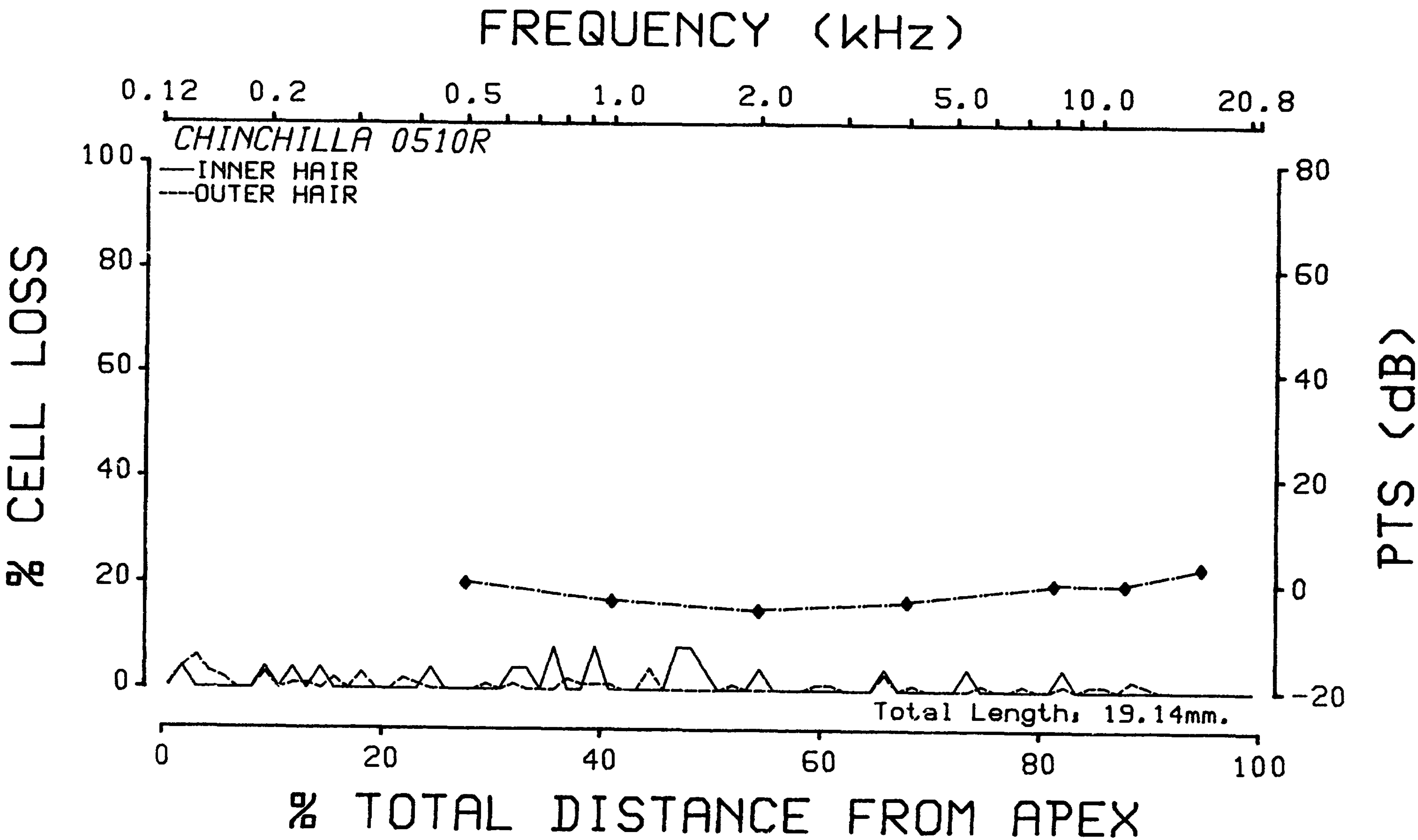
150 dB 10X 10/M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

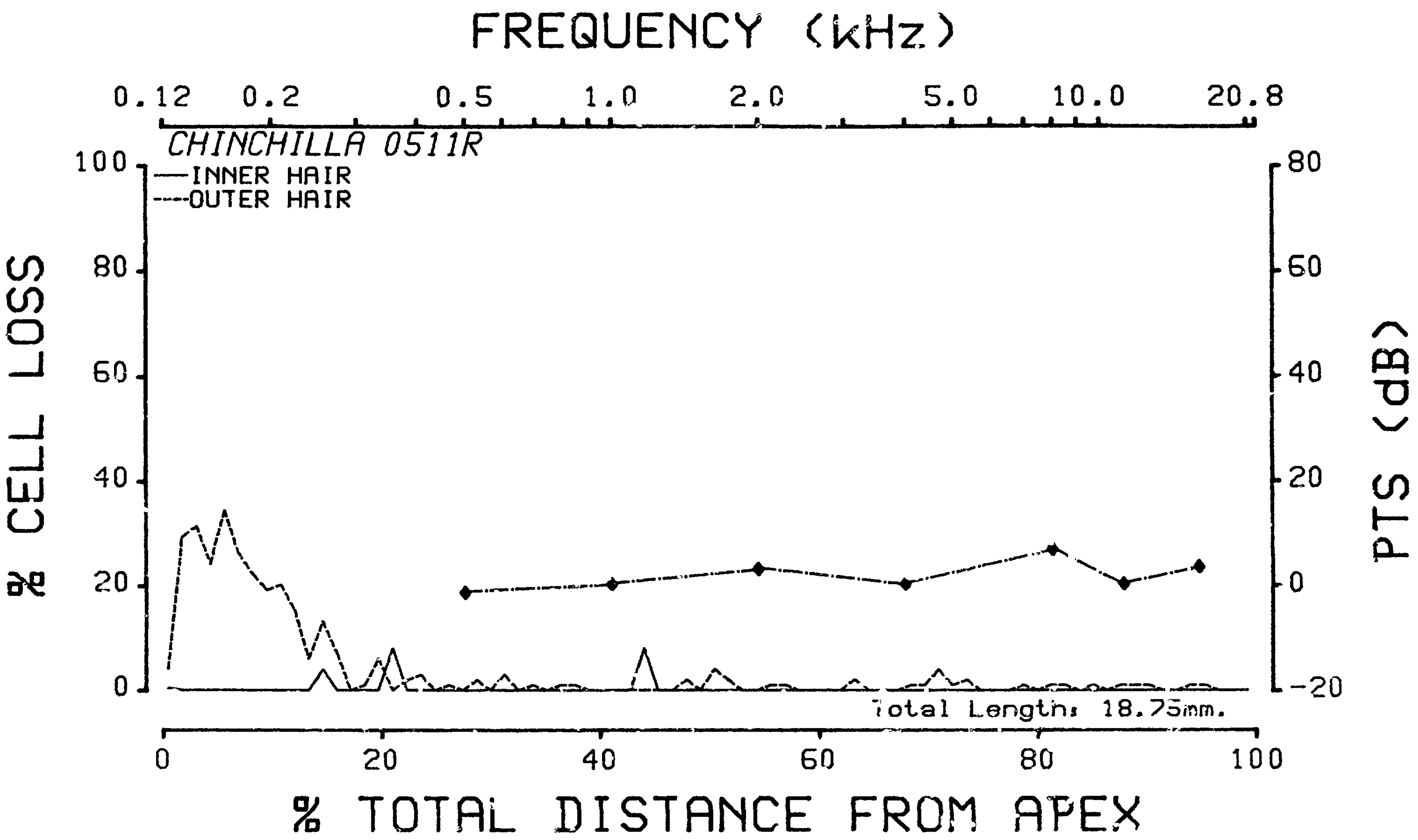
	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0513							
0.125 kHz	8	6	12	22	40	0	1
0.25 kHz	12	12	25	37	74	0	1
0.5 kHz	17	14	37	35	86	0	0
1 kHz	3	10	18	30	58	0	0
2 kHz	2	6	10	61	77	0	0
4 kHz	0	4	9	27	40	0	0
8 kHz	1	9	9	17	35	1	0
16 kHz	11	13	10	9	32	0	2
TOTALS	54	74	130	238	442	1	4
CHINCHILLA 0524							
0.125 kHz	0	9	14	49	72	0	0
0.25 kHz	0	0	2	29	31	0	0
0.5 kHz	0	11	3	11	25	0	0
1 kHz	0	2	15	4	21	0	0
2 kHz	0	0	2	1	3	0	0
4 kHz	0	3	3	13	19	0	0
8 kHz	0	1	0	2	3	0	0
16 kHz	0	0	0	1	1	0	0
TOTALS	0	26	39	110	175	0	0
GROUP MEANS							
0.125 kHz	2.4	14.2	25.4	27.6	67.2	0.0	0.4
0.25 kHz	3.2	4.6	13.6	31.0	49.2	0.0	0.2
0.5 kHz	4.4	7.0	10.0	11.8	28.8	0.0	0.0
1 kHz	2.2	38.2	57.0	10.8	106.0	0.6	1.0
2 kHz	1.2	8.6	13.0	14.4	36.0	0.0	0.2
4 kHz	0.4	3.0	3.6	8.8	15.4	0.0	0.2
8 kHz	0.4	3.0	3.2	4.8	11.0	0.2	0.0
16 kHz	2.8	3.4	3.4	4.2	11.0	0.0	0.4
TOTALS	17.0	82.0	129.2	113.4	324.6	0.8	2.4

Cochleograms and PTS Audiograms

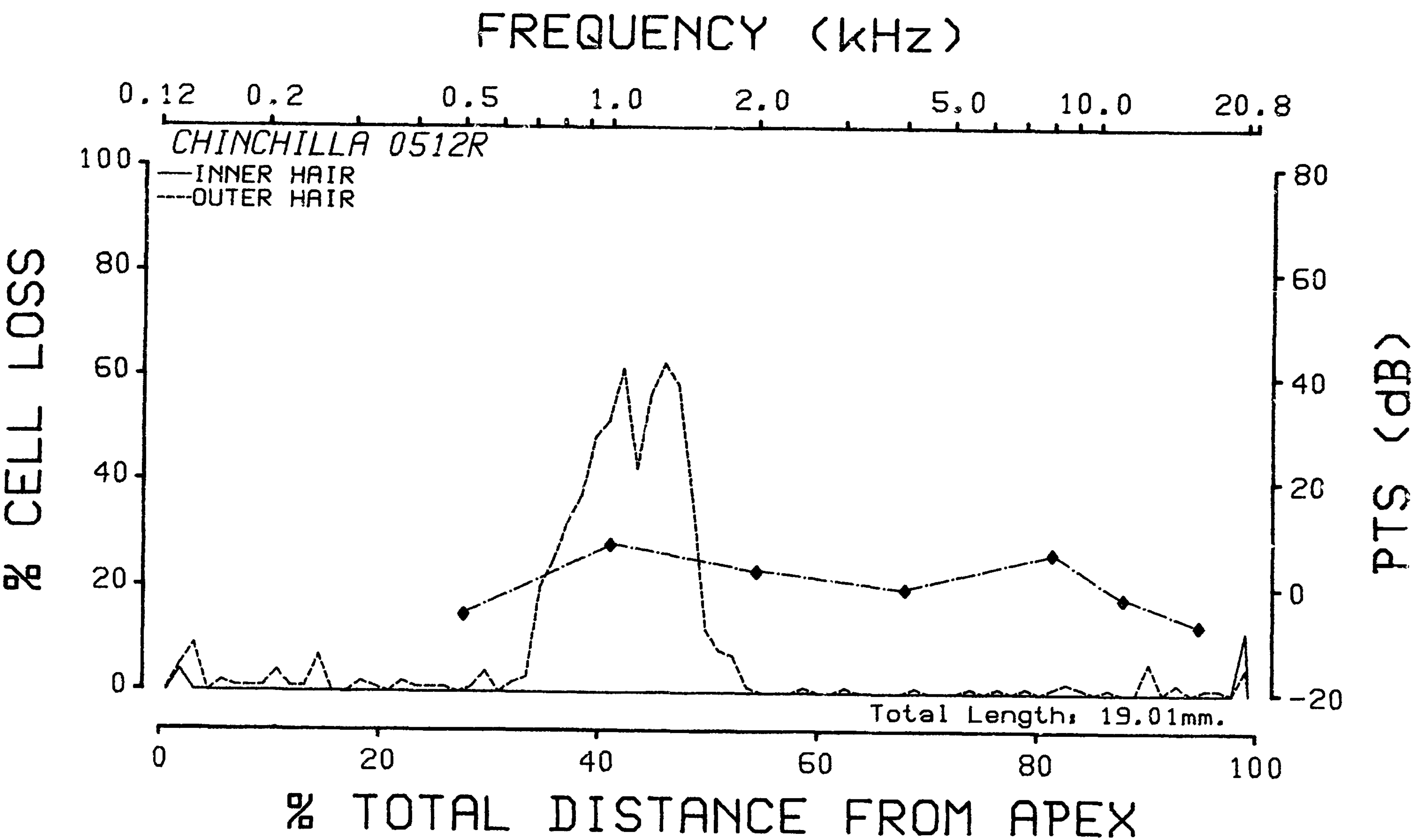
for Individual Animals

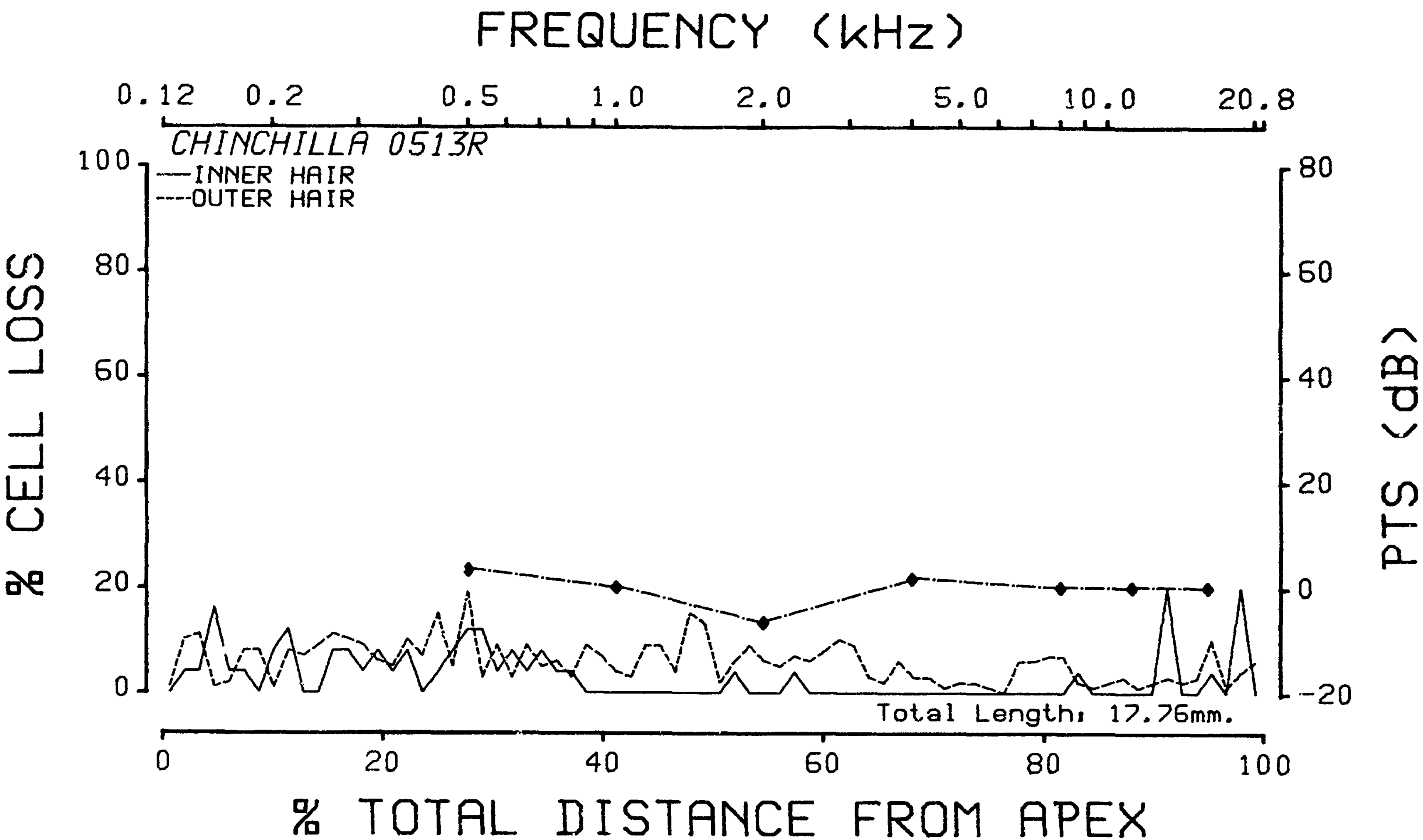


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0510R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 19.14mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

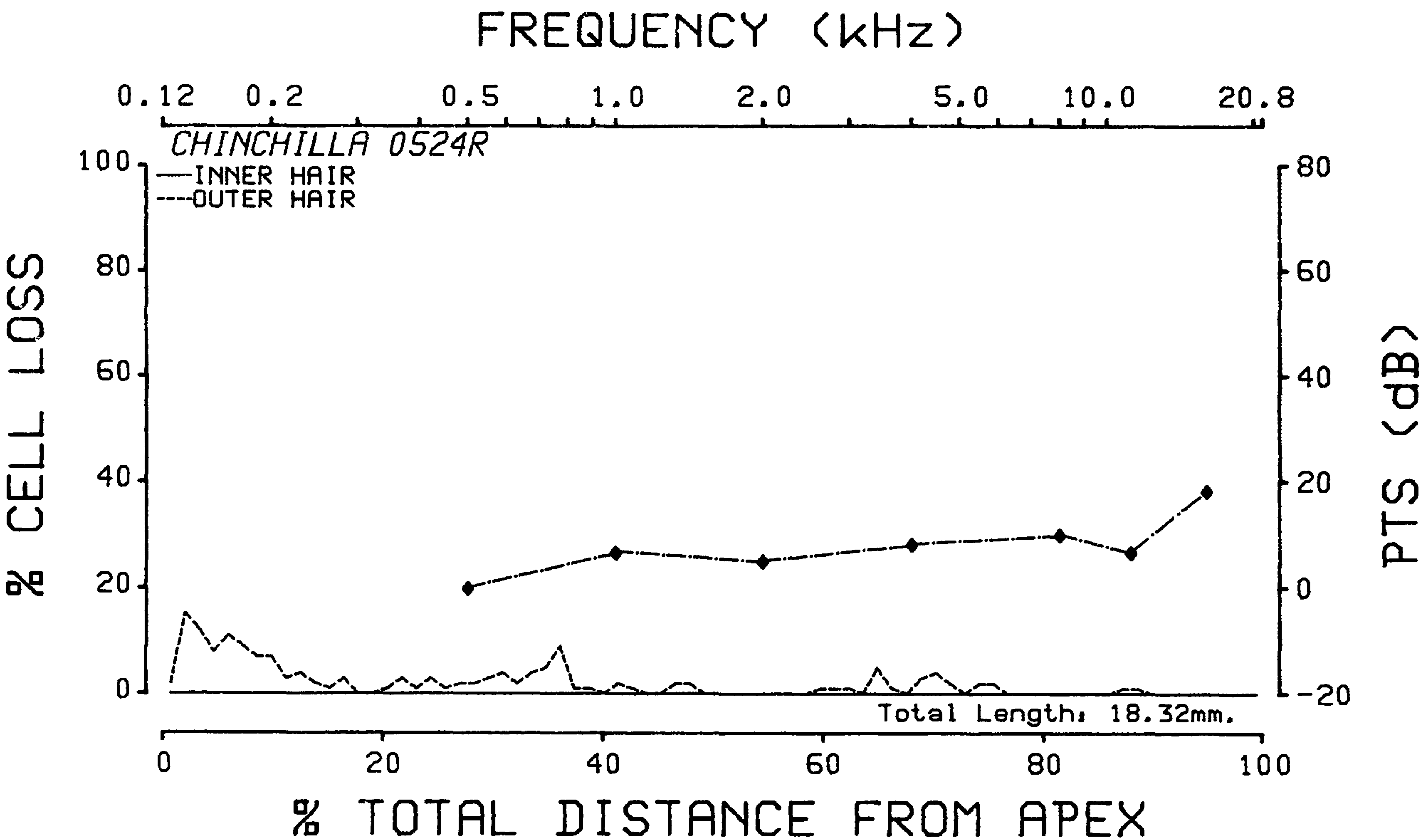


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0511R
INNER HAIR
OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.75mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0512R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
−20
Total Length: 19.01mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0513R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.76mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0524R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.32mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

Summary Data for the Group Exposed to:

150 dB, 10X, 1/10M

Animal #		
0502	-	Completed the Entire Protocol
0504	-	Completed the Entire Protocol
0505	-	Completed the Entire Protocol
0507	-	Completed the Entire Protocol
0509	-	Completed the Entire Protocol

150 dB 10X 1/10M

PRE-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0502	27.5	5.8	5.8	-2.5	20.8	9.2	19.2
0504	22.5	9.2	10.8	5.8	23.8	6.2	26.3
0505	22.5	12.5	19.2	14.2	22.5	12.5	17.5
0507	29.2	10.8	19.2	14.2	19.2	22.5	39.2
0509	22.5	12.5	19.2	10.8	22.5	20.8	30.6
Mean	24.8	10.2	14.8	8.5	21.8	14.3	26.6
S.D.	3.3	2.8	6.2	7.0	1.8	7.2	8.9

POST-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0502	20.8	5.8	2.5	-4.2	15.8	9.2	20.8
0504	22.5	5.8	10.8	2.5	19.2	2.5	32.5
0505	20.8	12.5	24.2	14.2	22.5	12.5	10.8
0507	24.2	10.8	25.8	14.2	25.8	22.5	37.5
0509	32.5	14.2	27.5	14.2	29.2	20.8	27.5
Mean	24.2	9.8	18.2	8.2	22.5	13.5	25.8
S.D.	4.9	3.8	11.0	8.6	5.3	8.3	10.4

PERMANENT THRESHOLD SHIFT (dB)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0502	-6.7	0.0	-3.3	-1.7	-5.0	0.0	1.7
0504	0.0	-3.3	0.0	-3.3	-4.6	-3.7	6.2
0505	-1.7	0.0	5.0	0.0	0.0	0.0	-6.7
0507	-5.0	0.0	6.7	0.0	6.7	0.0	-1.7
0509	10.0	1.7	8.3	3.3	6.7	0.0	-3.3
Mean	-0.7	-0.3	3.3	-0.3	0.7	-0.7	-0.7
S.D.	6.5	1.8	4.9	2.5	5.8	1.7	4.9

150 dB 10X 1/10M

TEMPORARY THRESHOLD SHIFT (dB)

Frequency 0.5 kHz

Animal\Hr	0	2	8	24	240	Max
0502	0.0	-5.0	-5.0	-5.0	-5.0	0.0
0504	15.0	10.0	5.0	0.0	0.0	15.0
0505	5.0	10.0	0.0	0.0	0.0	10.0
0507	8.3	-1.7	-1.7	-1.7	-6.7	8.3
0509	40.0	40.0	15.0	15.0	5.0	40.0
Mean	13.7	10.7	2.7	1.7	-1.3	14.7
S.D.	15.7	17.7	7.8	7.7	4.6	15.2

Frequency 2.0 kHz

Animal\Hr	0	2	8	24	240	Max
0502	26.7	16.7	6.7	1.7	1.7	26.7
0504	36.7	31.7	21.7	11.7	6.7	36.7
0505	8.3	33.3	8.3	3.3	3.3	33.3
0507	43.3	23.3	13.3	18.3	-1.7	43.3
0509	53.3	43.3	38.3	23.3	3.3	53.3
Mean	33.7	29.7	17.7	11.7	2.7	38.7
S.D.	17.2	10.2	12.9	9.4	3.0	10.2

Frequency 8.0 kHz

Animal\Hr	0	2	8	24	240	Max
0502	6.7	1.7	-3.3	-8.3	-8.3	6.7
0504	18.7	8.7	-1.2	-1.2	-1.2	18.7
0505	5.0	10.0	5.0	0.0	5.0	10.0
0507	13.3	18.3	3.3	8.3	8.3	18.3
0509	40.0	20.0	15.0	5.0	0.0	40.0
Mean	16.8	11.8	3.7	0.7	0.7	18.7
S.D.	14.1	7.5	7.1	6.4	6.4	13.0

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 1/10M

Probe Frequency: 0.5 kHz

Masker (kHz):		0.150	0.200	0.300	0.400	0.520	0.600	0.650	0.750	1.300	2.200
Animal	(Q-10 dB)					Pre-Exposure					
0502	(1.55)	77.5	72.5	62.5	47.5	42.5	42.5	47.5	57.5	87.5	95.0*
0504	(1.12)	67.5	72.5	57.5	47.5	42.5	47.5	47.5	47.5	82.5	95.0*
0505	(1.61)	72.5	67.5	57.5	47.5	42.5	42.5	37.5	42.5	82.5	95.0*
0507	(2.61)	72.5	67.5	57.5	47.5	37.5	47.5	47.5	52.5	82.5	95.0*
0509	(1.35)	67.5	67.5	57.5	42.5	37.5	42.5	37.5	47.5	77.5	95.0*
Mean	(1.65)	71.5	69.5	58.5	46.5	40.5	44.5	43.5	49.5	82.5	95.0
S.D.	(0.57)	4.2	2.7	2.2	2.2	2.7	2.7	5.5	5.7	3.5	0.0
Animal	(Q-10 dB)					Post-Exposure					
0502	(1.49)	72.5	62.5	52.5	42.5	32.5	32.5	37.5	42.5	67.5	82.5
0504	(0.78)	72.5	62.5	52.5	42.5	42.5	42.5	42.5	47.5	62.5	95.0*
0505	(1.33)	72.5	62.5	52.5	47.5	37.5	37.5	37.5	42.5	92.5	95.0*
0507	(1.63)	67.5	62.5	52.5	42.5	42.5	37.5	37.5	52.5	67.5	95.0*
0509	(1.69)	77.5	72.5	62.5	62.5	52.5	52.5	52.5	47.5	77.5	95.0*
Mean	(1.38)	72.5	64.5	54.5	47.5	41.5	40.5	41.5	46.5	77.5	92.5
S.D.	(0.36)	3.5	4.5	4.5	8.7	7.4	7.6	6.5	4.2	10.6	5.6

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 1/10M

Probe Frequency: 1.0 kHz

Masker (kHz):		0.150	0.200	0.400	0.550	0.800	1.050	1.300	1.700	1.900	2.500
Animal	(Q-10 dB)					Pre-Exposure					
0502	(2.10)	87.5	72.5	57.5	47.5	37.5	27.5	37.5	56.5	62.5	72.5
0504	(1.69)	82.5	67.5	57.5	52.5	37.5	27.5	32.5	47.5	72.5	91.0*
0505	(1.77)	77.5	77.5	62.5	52.5	37.5	32.5	42.5	57.5	72.5	87.5
0507	(1.84)	77.5	77.5	52.5	47.5	37.5	27.5	32.5	57.5	72.5	82.5
0509	(2.47)	82.5	82.5	67.5	57.5	52.5	37.5	47.5	62.5	72.5	91.0*
Mean	(1.97)	81.5	75.5	59.5	51.5	40.5	30.5	38.5	56.3	70.5	84.9
S.D.	(0.32)	4.2	5.7	5.7	4.2	6.7	4.5	6.5	5.4	4.5	7.8
Animal	(Q-10 dB)					Post-Exposure					
0502	(2.47)	77.5	67.5	52.5	47.5	37.5	22.5	32.5	52.5	77.5	82.5
0504	(2.55)	82.5	67.5	52.5	47.5	27.5	17.5	32.5	52.5	72.5	82.5
0505	(2.55)	82.5	77.5	62.5	47.5	37.5	27.5	42.5	62.5	62.5	91.0*
0507	(1.78)	67.5	72.5	57.5	52.5	37.5	27.5	32.5	52.5	57.5	91.0*
0509	(3.13)	82.5	82.5	67.5	62.5	42.5	27.5	42.5	62.5	62.5	87.5
Mean	(2.50)	78.5	73.5	58.5	51.5	36.5	24.5	36.5	56.5	66.5	86.9
S.D.	(0.48)	6.5	6.5	6.5	6.5	5.5	4.5	5.5	5.5	8.2	4.3

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 1/10M

Probe Frequency: 2.0 kHz

Masker (kHz):		0.300	0.750	0.900	1.300	1.700	2.050	2.200	3.000	3.500	4.000
Animal (Q-10 dB)						Pre-Exposure					
0502	(3.02)	77.5	47.5	42.5	32.5	32.5	22.5	27.5	47.5	62.5	87.5
0504	(2.97)	67.5	47.5	42.5	37.5	27.5	22.5	17.5	47.5	47.5	57.5
0505	(1.62)	77.5	57.5	52.5	42.5	37.5	32.5	37.5	47.5	62.5	96.0*
0507	(1.75)	82.5	72.5	57.5	32.5	32.5	27.5	32.5	52.5	67.5	87.5
0509	(2.44)	77.5	52.5	47.5	47.5	52.5	32.5	32.5	47.5	62.5	96.0*
Mean	(2.36)	76.5	55.5	48.5	38.5	36.5	27.5	29.5	48.5	60.5	84.9
S.D.	(0.66)	5.5	10.4	6.5	6.5	9.6	5.0	7.6	2.2	7.5	15.9
Animal (Q-10 dB)						Post-Exposure					
0502	(2.53)	72.5	42.5	42.5	37.5	27.5	22.5	17.5	37.5	47.5	62.5
0504	(2.19)	72.5	52.5	47.5	47.5	32.5	27.5	27.5	52.5	62.5	92.5
0505	(0.65)	77.5	47.5	52.5	47.5	42.5	47.5	42.5	47.5	52.5	96.0*
0507	(1.17)	72.5	47.5	37.5	37.5	37.5	32.5	32.5	52.5	62.5	62.5
0509	(1.69)	72.5	52.5	42.5	47.5	47.5	42.5	37.5	47.5	67.5	96.0*
Mean	(1.65)	73.5	48.5	44.5	43.5	37.5	34.5	31.5	47.5	58.5	81.9
S.D.	(0.76)	2.2	4.2	5.7	5.5	7.9	10.4	9.6	6.1	8.2	17.8

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 1/10M

Probe Frequency: 4.0 kHz

Masker (kHz):		0.450	1.300	2.200	3.000	3.500	4.100	4.500	5.000	5.600	6.000
Animal	(Q-10 dB)					Pre-Exposure					
0502	(2.54)	77.5	52.5	47.5	42.5	22.5	27.5	27.5	47.5	67.5	77.5
0504	(2.89)	77.5	72.5	52.5	42.5	27.5	22.5	27.5	37.5	57.5	67.5
0505	(2.61)	77.5	62.5	57.5	47.5	32.5	32.5	42.5	47.5	72.5	82.5
0507	(3.44)	77.5	62.5	62.5	52.5	42.5	32.5	32.5	57.5	62.5	77.5
0509	(2.61)	77.5	62.5	52.5	42.5	27.5	27.5	37.5	42.5	57.5	67.5
Mean	(2.82)	77.5	62.5	54.5	45.5	30.5	28.5	33.5	46.5	63.5	74.5
S.D.	(0.37)	0.0	7.1	5.7	4.5	7.6	4.2	6.5	7.4	6.5	6.7
Animal	(Q-10 dB)					Post-Exposure					
0502	(3.13)	72.5	52.5	47.5	42.5	32.5	17.5	22.5	27.5	37.5	67.5
0504	(4.10)	72.5	52.5	42.5	47.5	27.5	17.5	27.5	42.5	47.5	72.5
0505	(2.89)	77.5	67.5	57.5	52.5	37.5	32.5	37.5	47.5	77.5	82.5
0507	(3.66)	72.5	62.5	62.5	47.5	32.5	22.5	27.5	47.5	57.5	82.5
0509	(2.61)	77.5	62.5	57.5	42.5	27.5	32.5	37.5	47.5	62.5	72.5
Mean	(3.28)	74.5	59.5	53.5	46.5	31.5	24.5	30.5	42.5	56.5	75.5
S.D.	(0.60)	2.7	6.7	8.2	4.2	4.2	7.6	6.7	8.7	15.2	6.7

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 1/10M

Probe Frequency: 8.0 kHz

Masker (kHz):		0.450	1.300	2.500	5.900	7.000	8.100	9.300	11.000	12.700	14.000
Animal	(Q-10 dB)					Pre-Exposure					
0502	(2.73)	92.5	62.5	57.5	42.5	42.5	37.5	32.5	47.5	62.5	72.5
0504	(3.00)	87.5	62.5	57.5	42.5	42.5	32.5	37.5	57.5	87.5	95.0*
0505	(4.58)	82.5	67.5	62.5	42.5	52.5	32.5	42.5	72.5	100.0*	95.0*
0507	(4.15)	77.5	52.5	57.5	37.5	37.5	22.5	32.5	57.5	62.5	95.0*
0509	(1.06)	77.5	67.5	52.5	37.5	42.5	37.5	52.5	62.5	82.5	92.5
Mean	(3.11)	83.5	62.5	57.5	40.5	43.5	32.5	39.5	59.5	79.0	90.0
S.D.	(1.38)	6.5	6.1	3.5	2.7	5.5	6.1	8.4	9.1	16.4	9.8
Animal	(Q-10 dB)					Post-Exposure					
0502	(1.44)	77.5	62.5	52.5	37.5	32.5	32.5	42.5	57.5	82.5	87.5
0504	(5.29)	87.5	62.5	57.5	47.5	62.5	27.5	37.5	62.5	97.5	92.5
0505	(4.58)	77.5	67.5	52.5	37.5	52.5	32.5	42.5	72.5	100.0*	100.0*
0507	(4.82)	82.5	62.5	77.5	42.5	47.5	37.5	57.5	72.5	92.5	87.5
0509	(1.87)	82.5	67.5	57.5	37.5	47.5	47.5	47.5	72.5	87.5	95.0*
Mean	(3.60)	81.5	64.5	59.5	40.5	48.5	35.5	45.5	67.5	92.0	92.5
S.D.	(1.80)	4.2	2.7	10.4	4.5	10.8	7.6	7.6	7.1	7.2	5.3

MASKED THRESHOLDS (dB SPL) Group: 150 dB 10X 1/10M

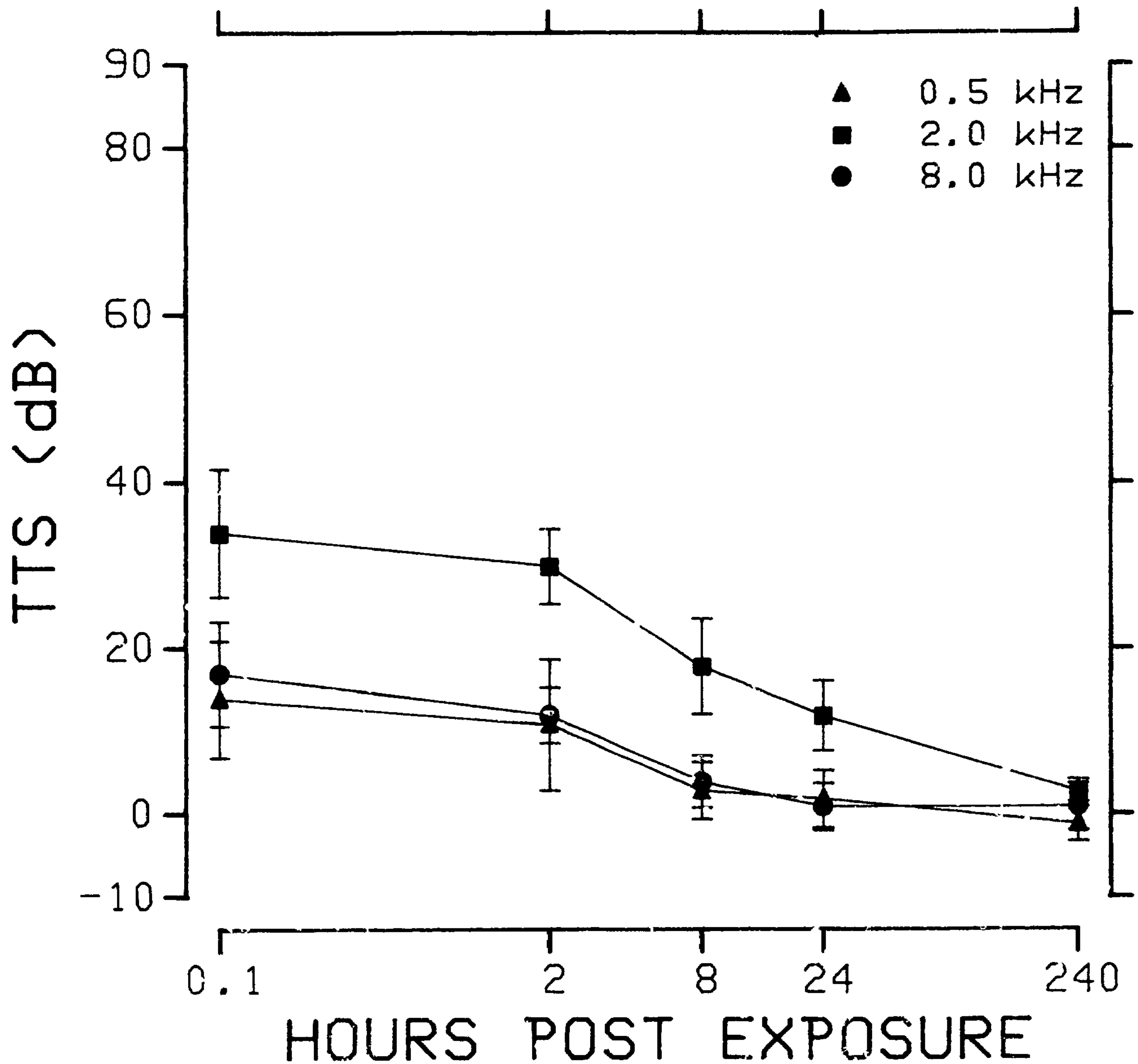
Probe Frequency: 11.2 kHz

Masker (kHz):		1.000	4.000	7.000	9.000	11.000	11.500	12.000	13.000	14.500	16.000
Animal	(Q-10 dB)					Pre-Exposure					
0502	(1.77)	77.5	72.5	62.5	47.5	42.5	47.5	47.5	42.5	52.5	72.5
0504	(5.67)	67.5	67.5	62.5	52.5	32.5	27.5	32.5	42.5	82.5	91.0*
0505	(3.77)	67.5	52.5	62.5	47.5	37.5	32.5	37.5	42.5	77.5	82.5
0507	(5.95)	67.5	62.5	62.5	52.5	27.5	32.5	37.5	52.5	82.5	91.0*
0509	(3.26)	77.5	67.5	62.5	52.5	37.5	42.5	42.5	47.5	62.5	82.5
Mean	(4.08)	71.5	64.5	62.5	50.5	35.5	36.5	39.5	45.5	71.5	83.9
S.D.	(1.74)	5.5	7.6	0.0	2.7	5.7	8.2	5.7	4.5	13.4	7.7
Animal	(Q-10 dB)					Post-Exposure					
0502	(10.87)	67.5	47.5	67.5	47.5	22.5	52.5	42.5	37.5	47.5	72.5
0504	(4.63)	62.5	52.5	62.5	42.5	22.5	22.5	27.5	42.5	72.5	82.5
0505	(5.75)	62.5	47.5	57.5	52.5	37.5	27.5	32.5	37.5	67.5	77.5
0507	(5.75)	67.5	57.5	67.5	52.5	37.5	27.5	32.5	37.5	67.5	87.5
0509	(5.36)	67.5	62.5	67.5	62.5	42.5	42.5	52.5	52.5	82.5	91.0*
Mean	(6.47)	65.5	53.5	64.5	51.5	32.5	34.5	37.5	41.5	67.5	82.2
S.D.	(2.50)	2.7	6.5	4.5	7.4	9.4	12.5	10.0	6.5	12.7	7.4

The Group Mean Recovery Curves

Measured at Three Test Frequencies

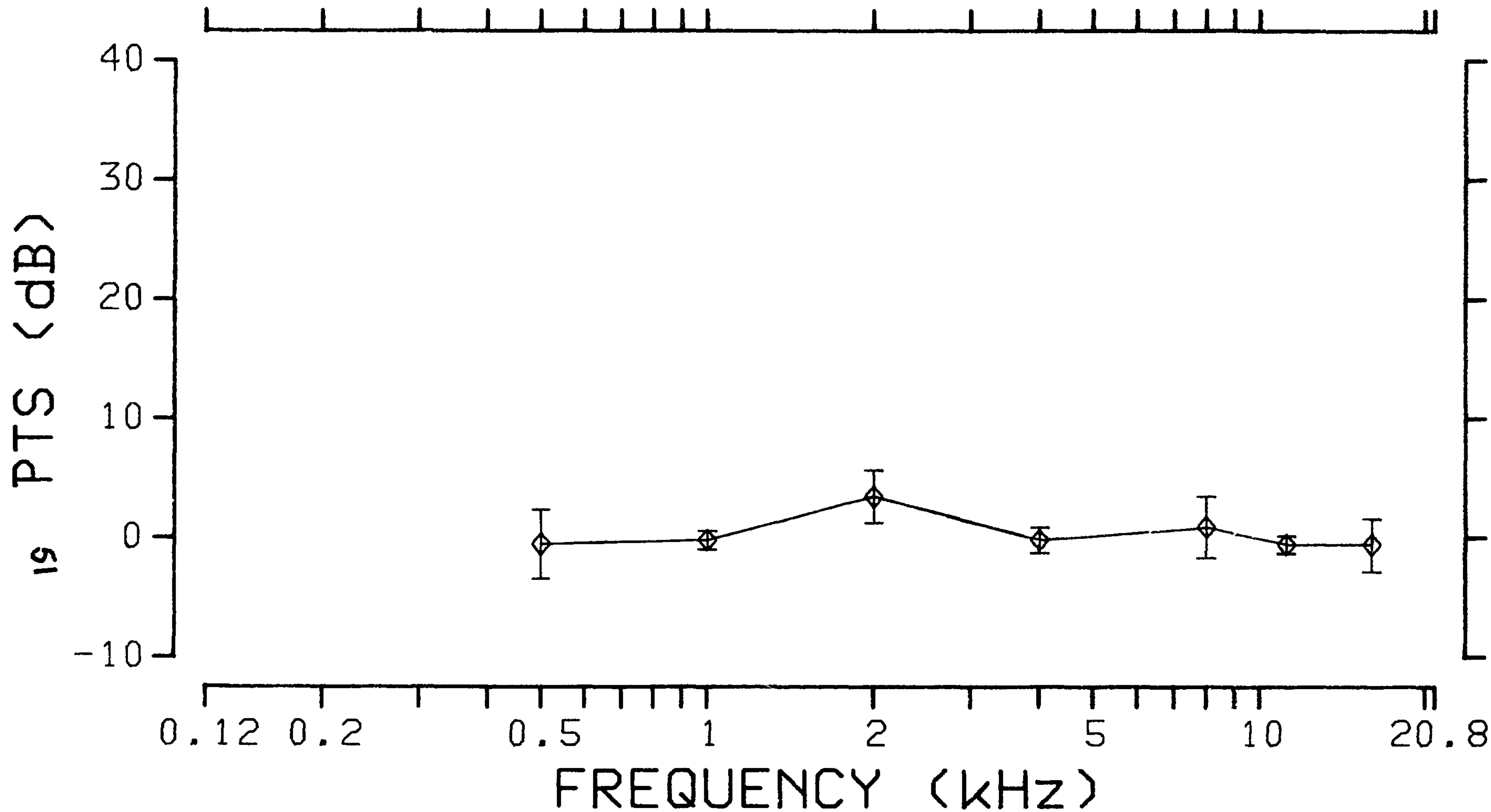
MEAN DATA (n=5) - 150 dB 10X 1/10M



The Group Mean Permanent Threshold Shift (PTS)

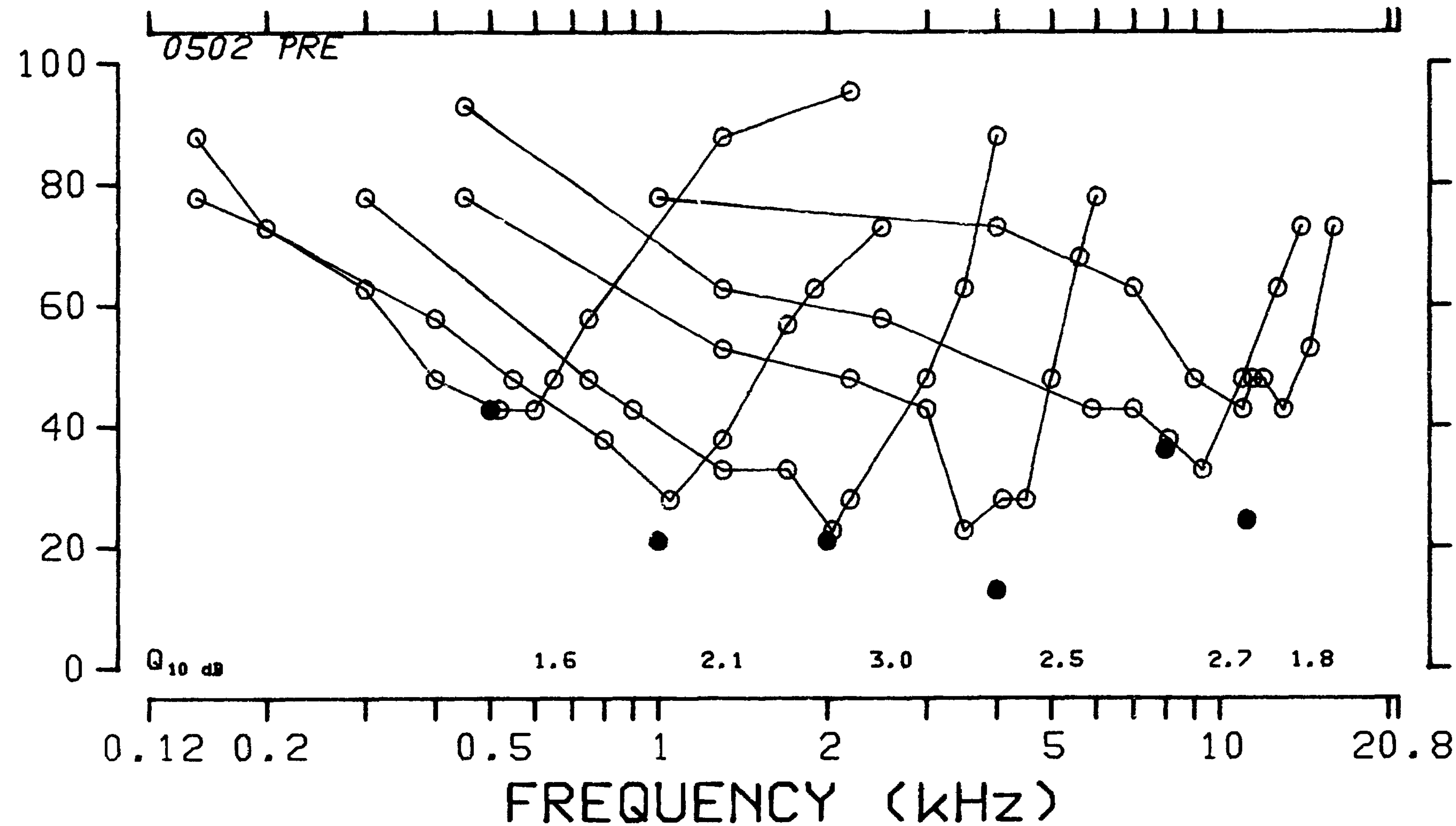
for all Test Frequencies

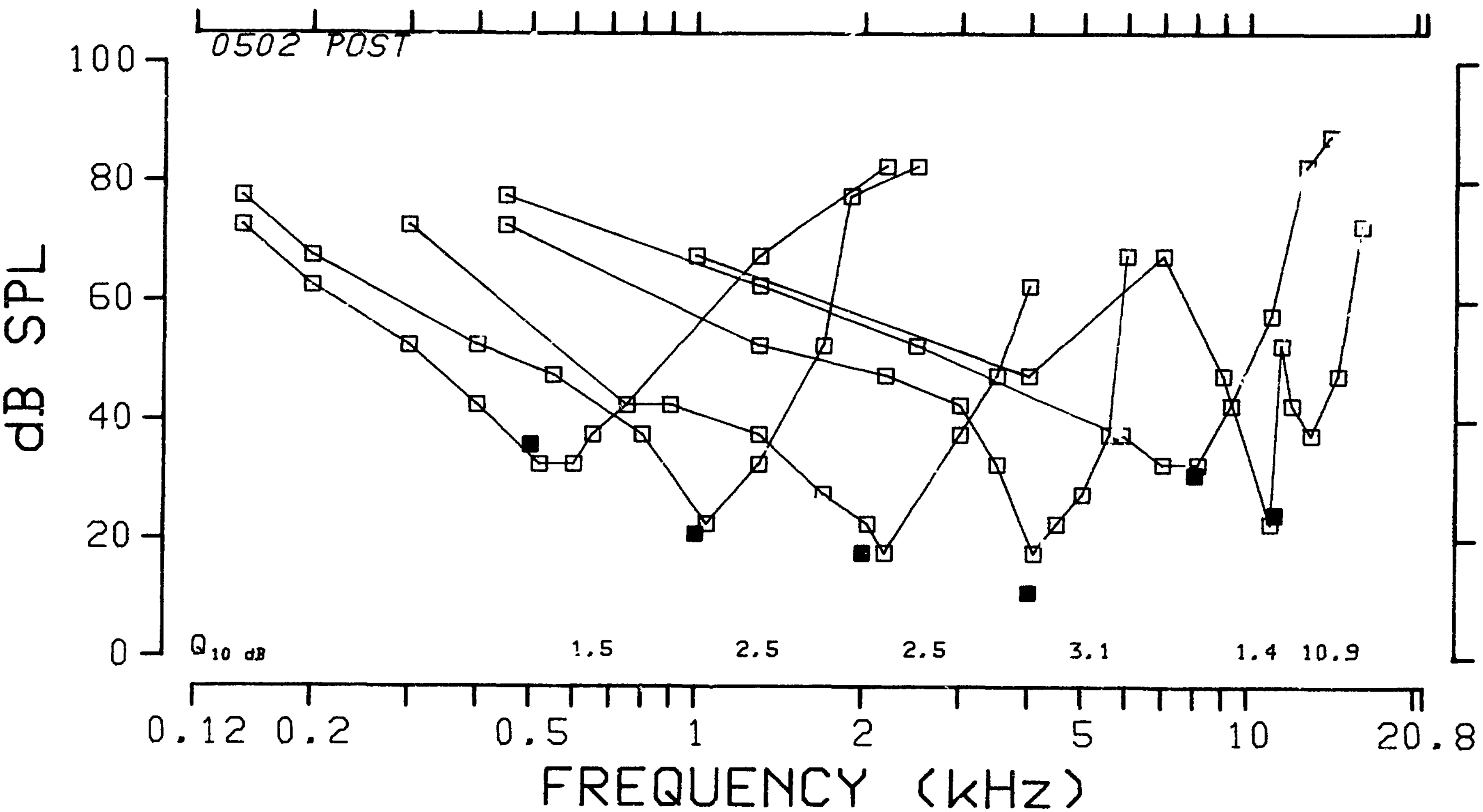
MEAN DATA (n=5) - 150 dB 10X 1/10M



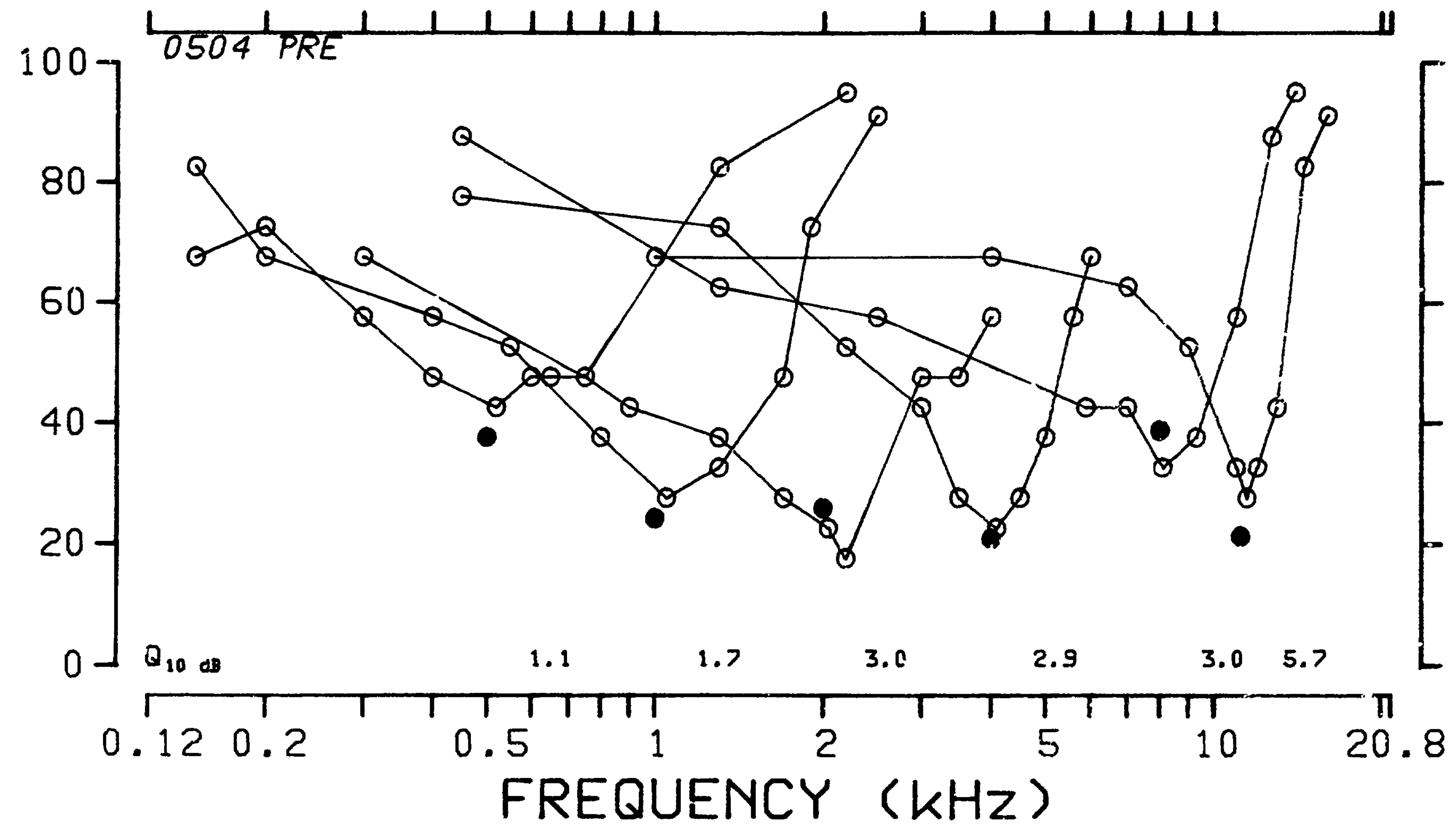
The Pre and Postexposure Tuning Curves for
Individual Animals in this Exposure Group.

The Solid Symbol represents the intensity of the probe tone.

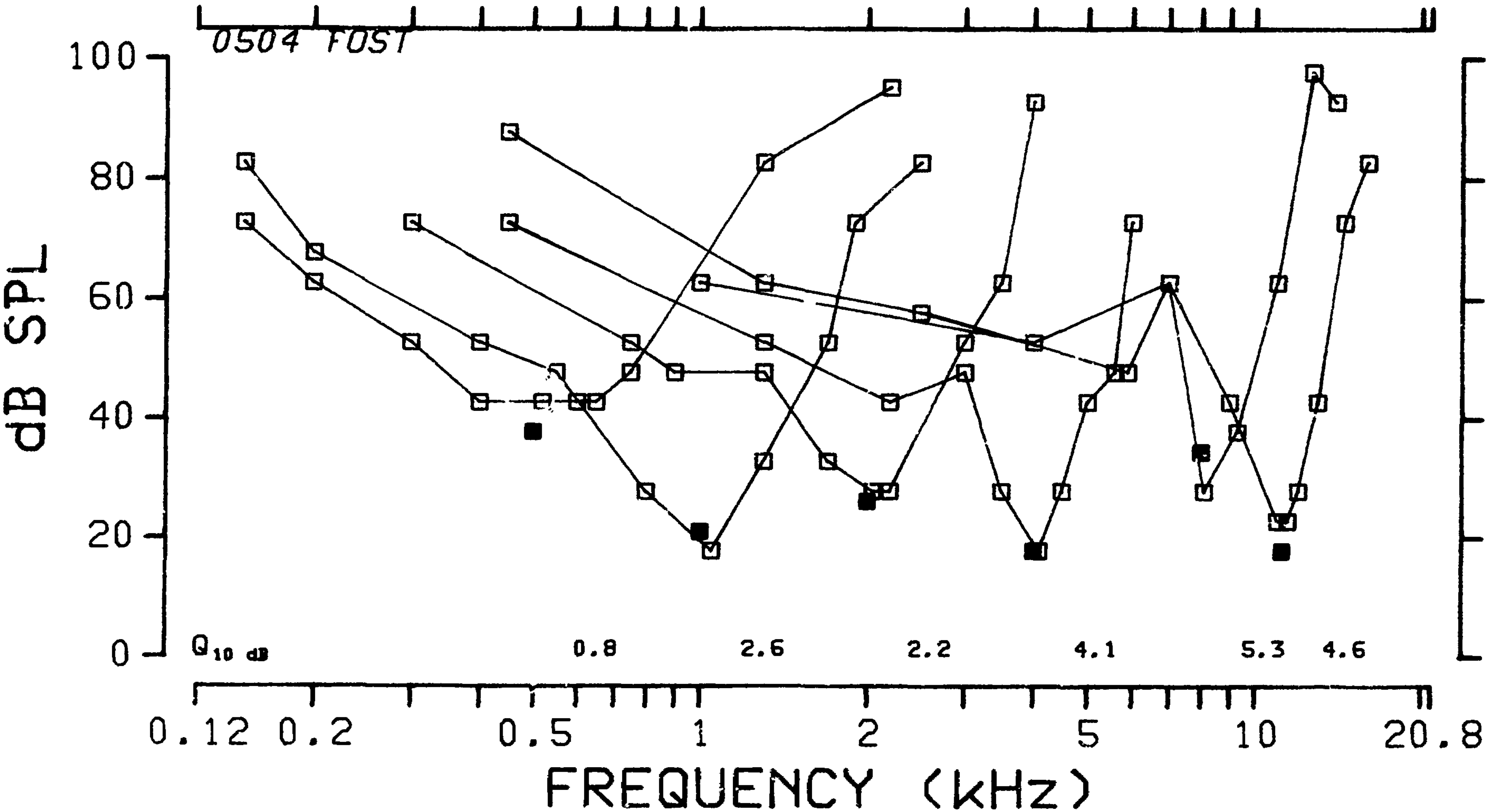

0502 PRE
100
80
60
40
20
0
dB SPL
$Q_{10\ dB}$
1.6
2.1
3.0
2.5
2.7
1.8
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

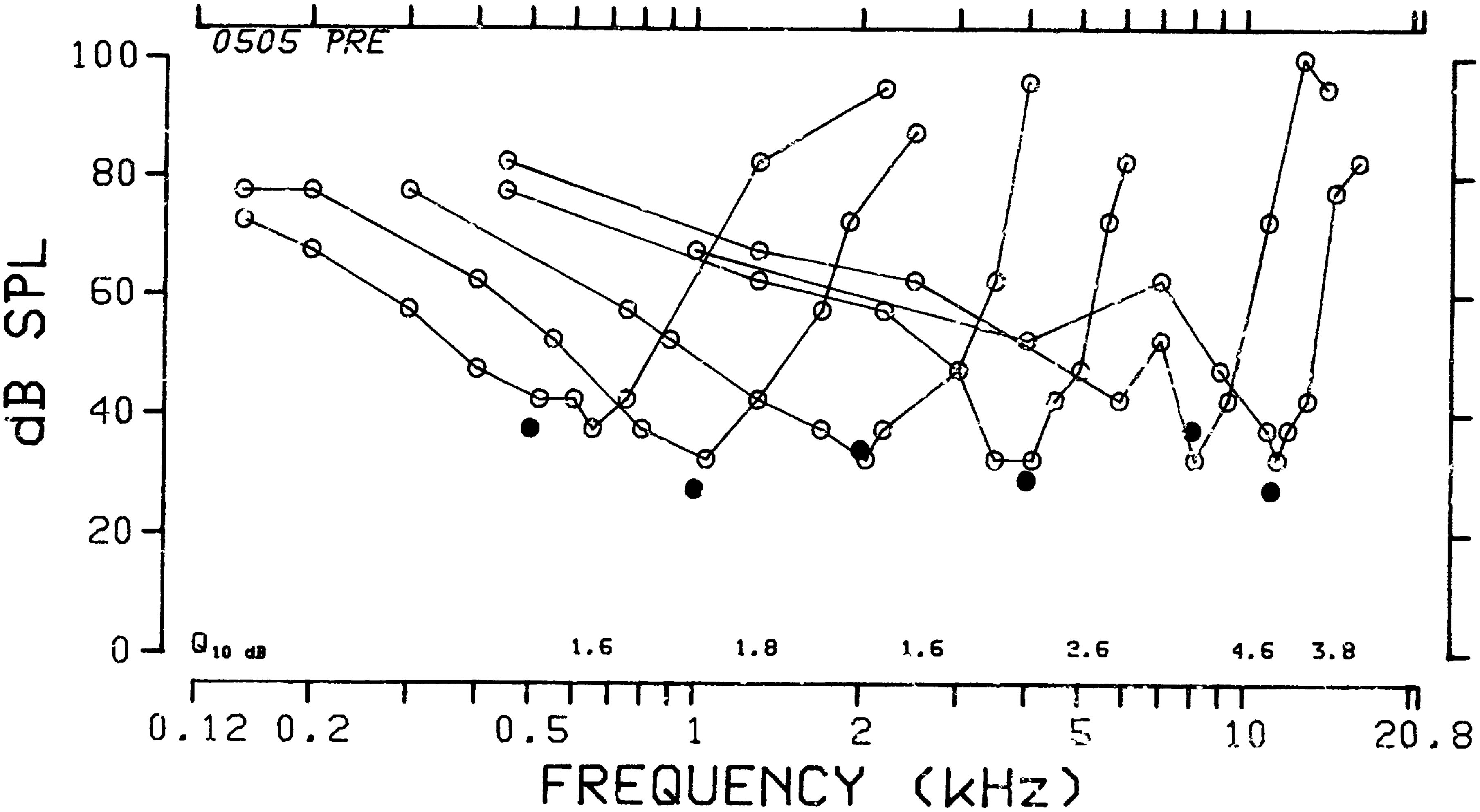


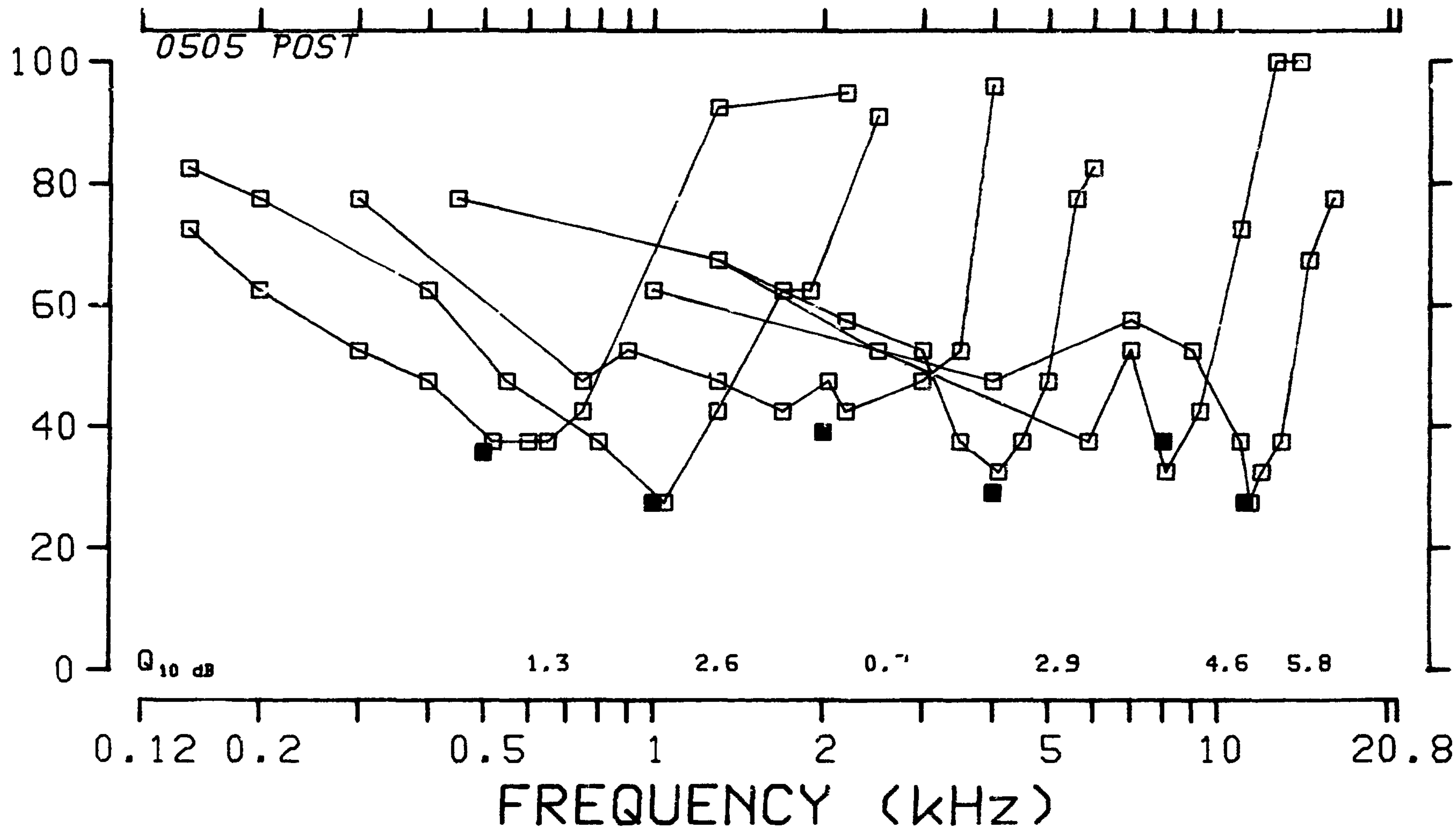
0502 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.5
2.5
2.5
3.1
1.4
10.9
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

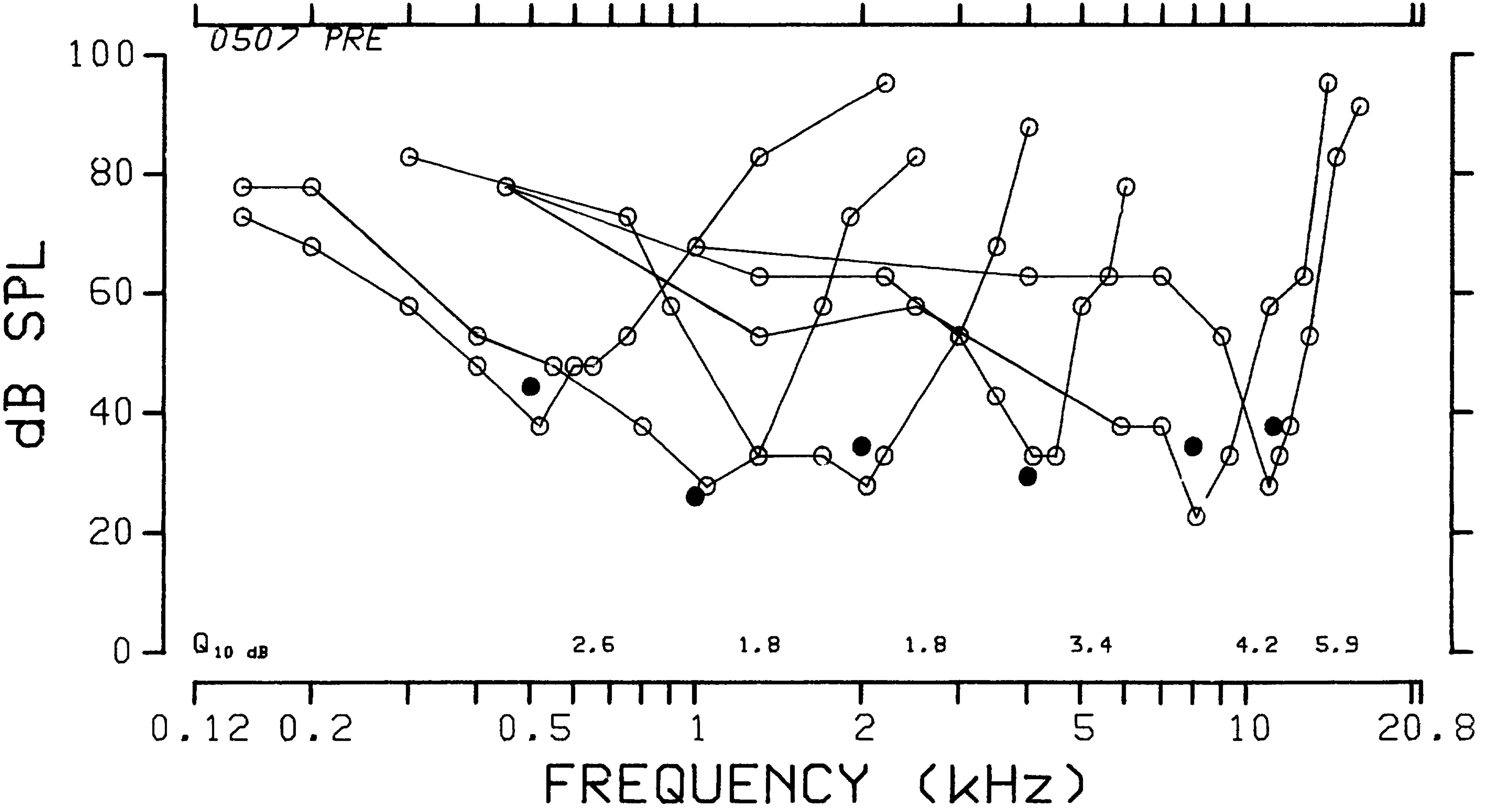


0504 PRE
100
80
60
40
20
0
dB SPL
$Q_{10\ dB}$
1.1
1.7
3.0
2.9
3.0
5.7
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

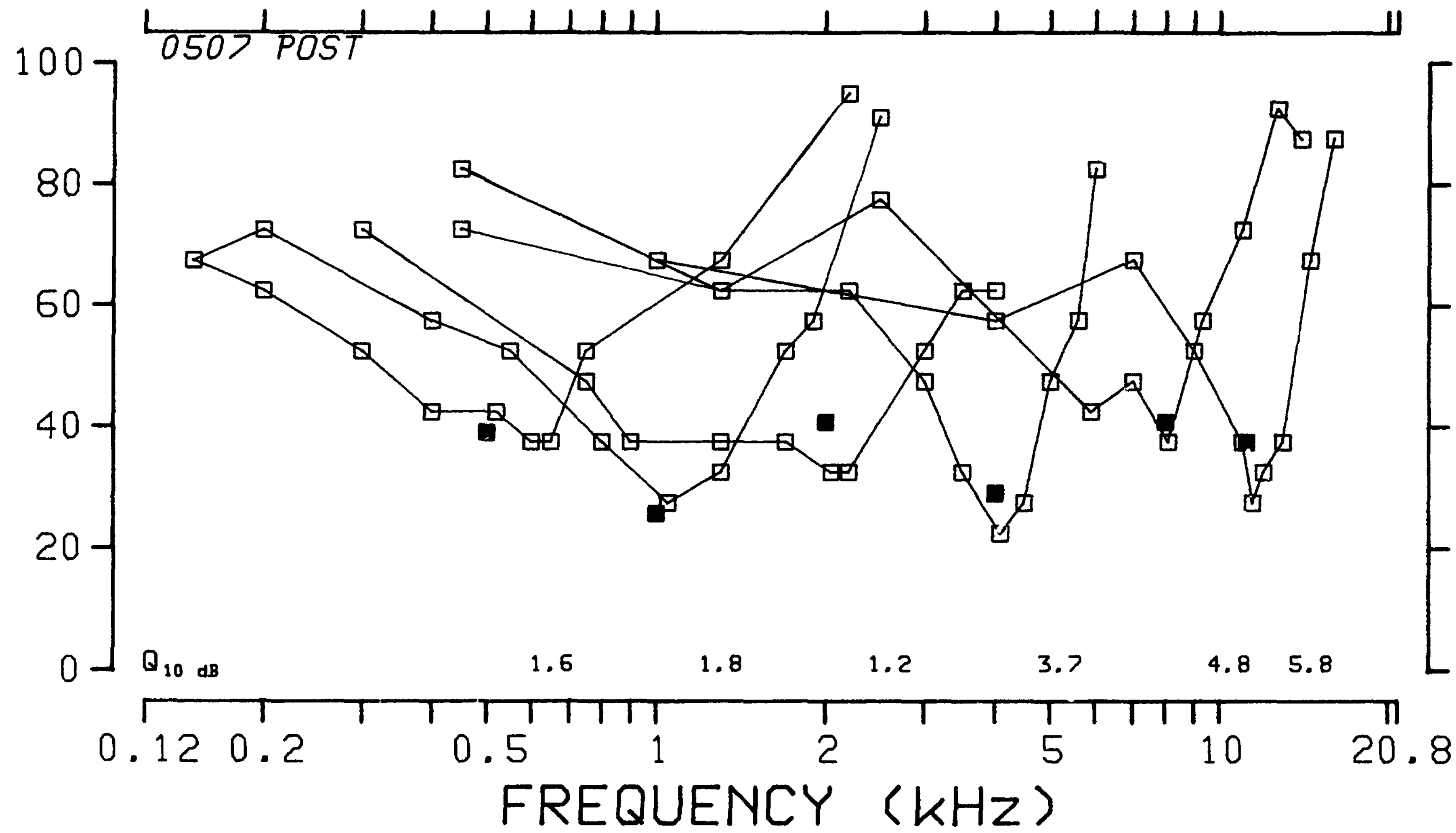

0504 FOST
dB SPL
100
80
60
40
20
0
Q10 dB
0.8
2.6
2.2
4.1
5.3
4.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0505 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
1.6
1.8
1.6
2.6
4.6
3.8
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

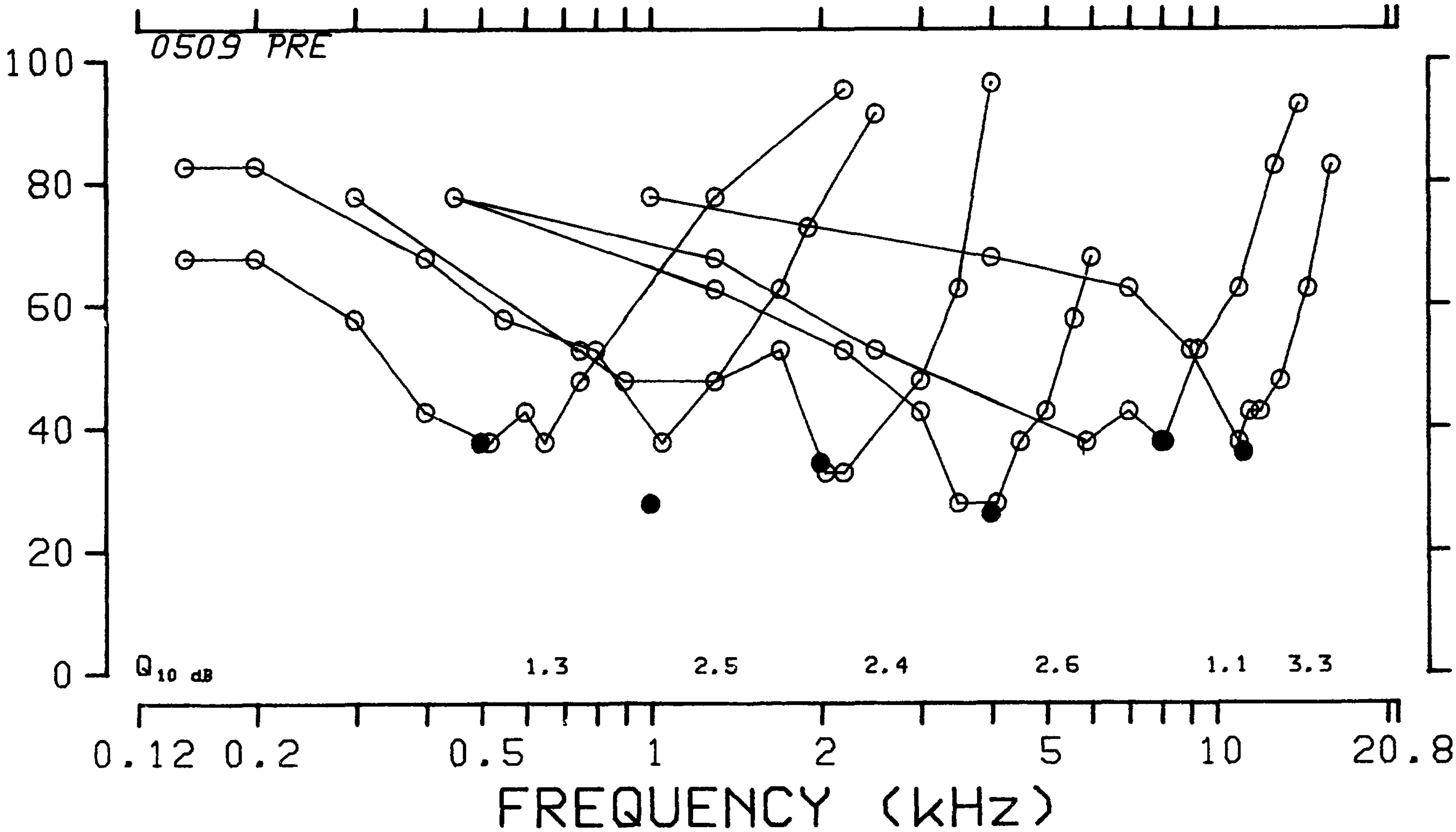

0505 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.3
2.6
0.⁻
2.9
4.6
5.8
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

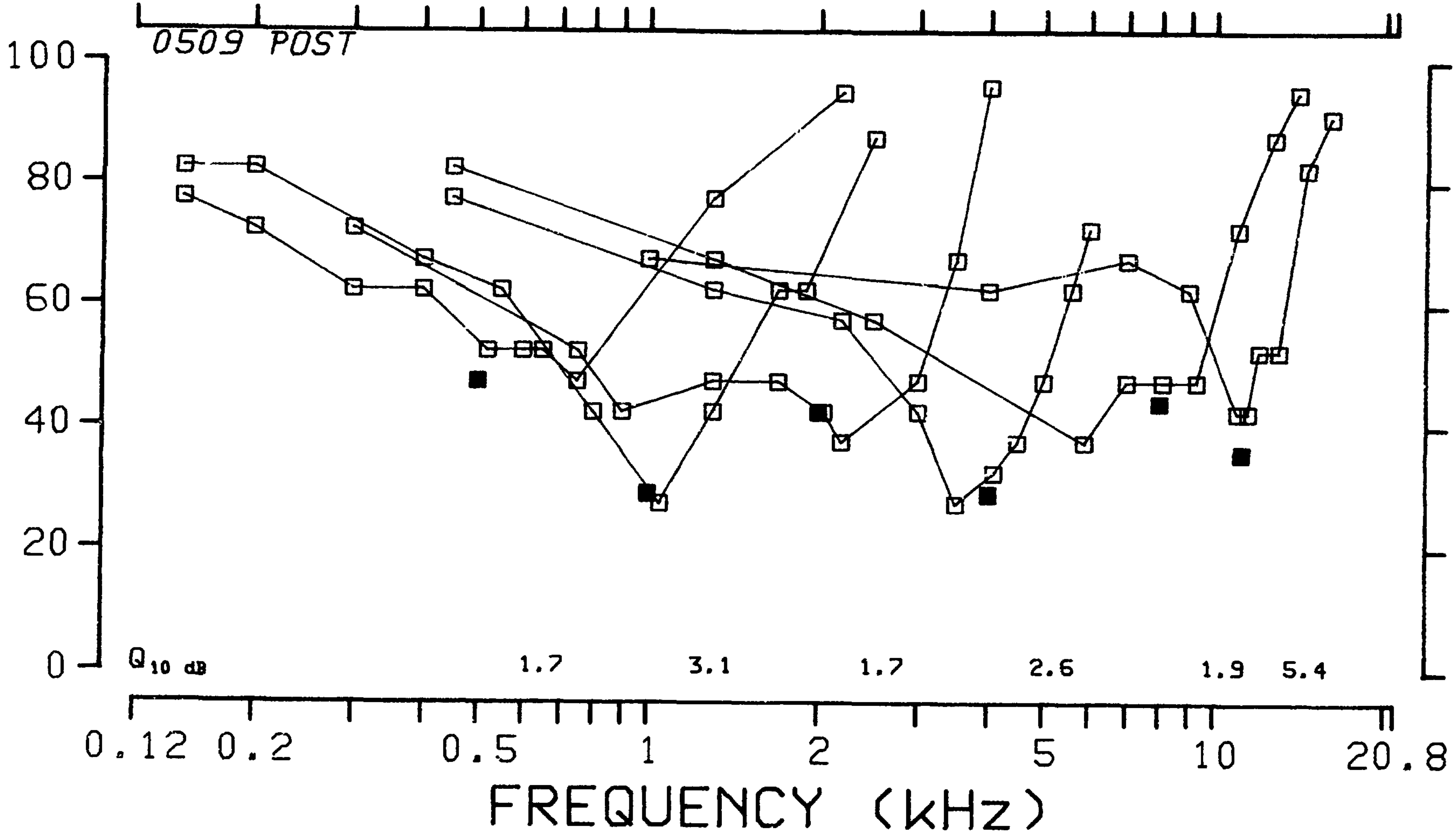


0507 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.6
1.8
1.8
3.4
4.2
5.9
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0507 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.6
1.8
1.2
3.7
4.8
5.8
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

60


0509 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
1.3
2.5
2.4
2.6
1.1
3.3
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0509 POST
100
80
60
40
20
0
dB SPL
Q10 dB
1.7
3.1
1.7
2.6
1.9
5.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

62

150 dB 10X 1/10M

TOTAL NUMBER OF COCHLEAR SENSORY CELLS MISSING

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0502	10	25	60	232	317
0504	15	48	50	68	166
0505	8	50	109	149	308
0507	8	23	29	46	98
0509	47	91	152	155	398
GROUP MEAN	18				257
S.D.	17				122
S.E.	7				55

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

	OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	OUTER HAIR CELLS
GROUP MEANS			
	0.125 kHz	1.0	58.4
	0.25 kHz	2.6	53.0
	0.5 kHz	1.2	37.4
	1 kHz	1.8	35.6
	2 kHz	2.2	19.0
	4 kHz	5.4	29.2
	8 kHz	2.0	17.4
	16 kHz	1.4	7.4
STANDARD DEVIATIONS			
	0.125 kHz	0.7	48.0
	0.25 kHz	1.8	45.0
	0.5 kHz	0.8	29.4
	1 kHz	2.9	29.1
	2 kHz	0.8	9.9
	4 kHz	9.4	40.4
	8 kHz	2.8	16.9
	16 kHz	1.1	6.7

150 dB 10K 1/10M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0502							
0.125 kHz	1	6	13	38	57	0	0
0.25 kHz	3	0	3	87	90	0	0
0.5 kHz	1	3	10	66	79	0	1
1 kHz	1	6	25	30	61	0	0
2 kHz	3	7	4	4	15	0	1
4 kHz	0	1	1	5	7	0	0
8 kHz	0	1	2	1	4	0	0
16 kHz	1	1	2	1	4	0	0
TOTALS	10	25	60	232	317	0	2
CHINCHILLA 0504							
0.125 kHz	0	0	6	16	22	0	5
0.25 kHz	3	0	1	8	9	0	0
0.5 kHz	1	2	5	13	20	0	1
1 kHz	0	7	7	4	18	0	3
2 kHz	2	12	6	4	22	0	5
4 kHz	3	11	10	9	30	4	7
8 kHz	0	15	14	14	43	4	9
16 kHz	0	1	1	0	2	0	0
TOTALS	15	48	50	68	166	8	30
CHINCHILLA 0505							
0.125 kHz	1	35	57	49	141	0	0
0.25 kHz	2	3	30	74	107	0	0
0.5 kHz	2	2	6	9	17	0	0
1 kHz	1	3	4	3	10	0	0
2 kHz	1	1	2	3	6	0	0
4 kHz	0	1	2	4	7	0	0
8 kHz	0	1	4	5	10	0	0
16 kHz	1	4	4	2	10	0	1
TOTALS	8	50	109	149	309	0	1

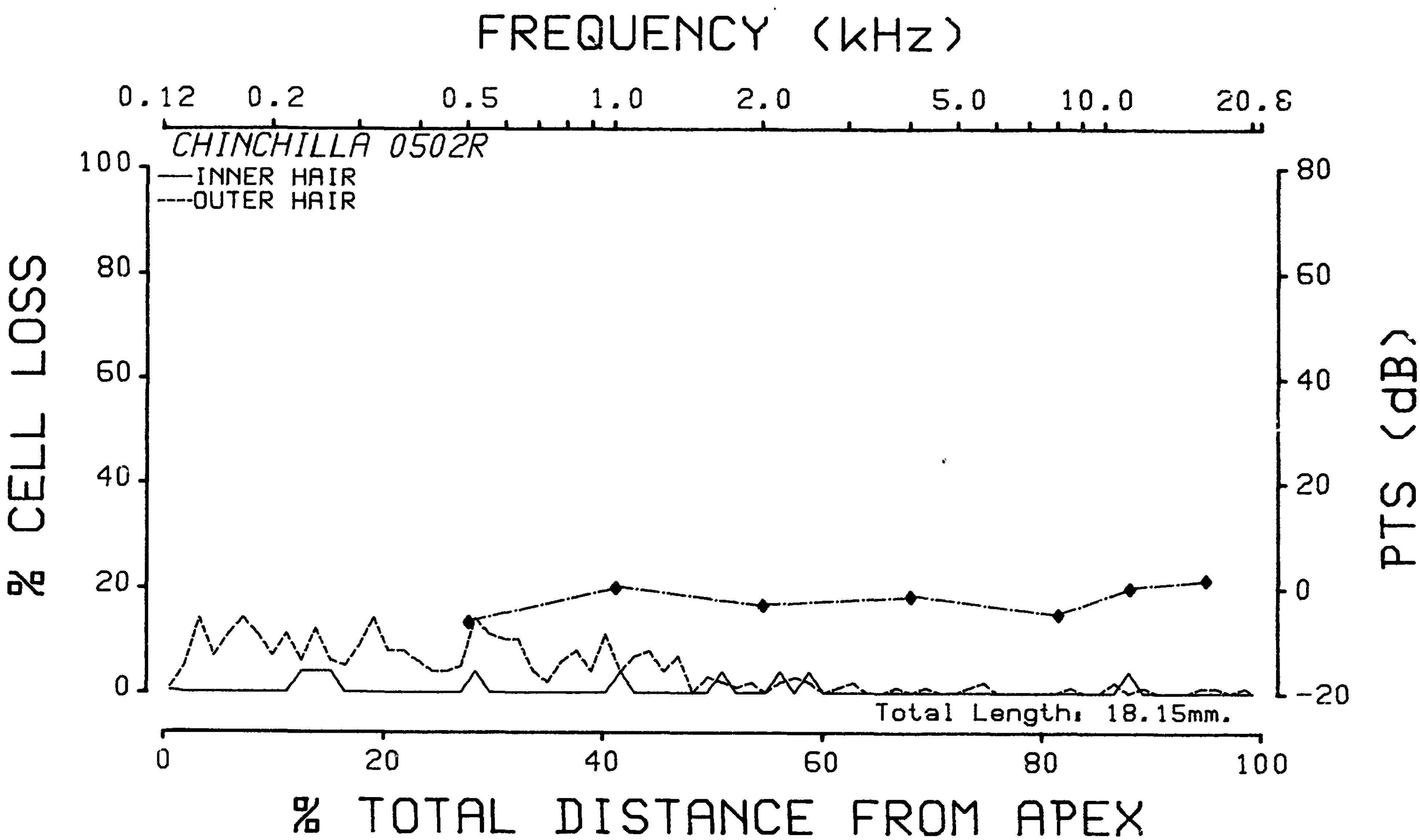
150 dB 10X 1/10M

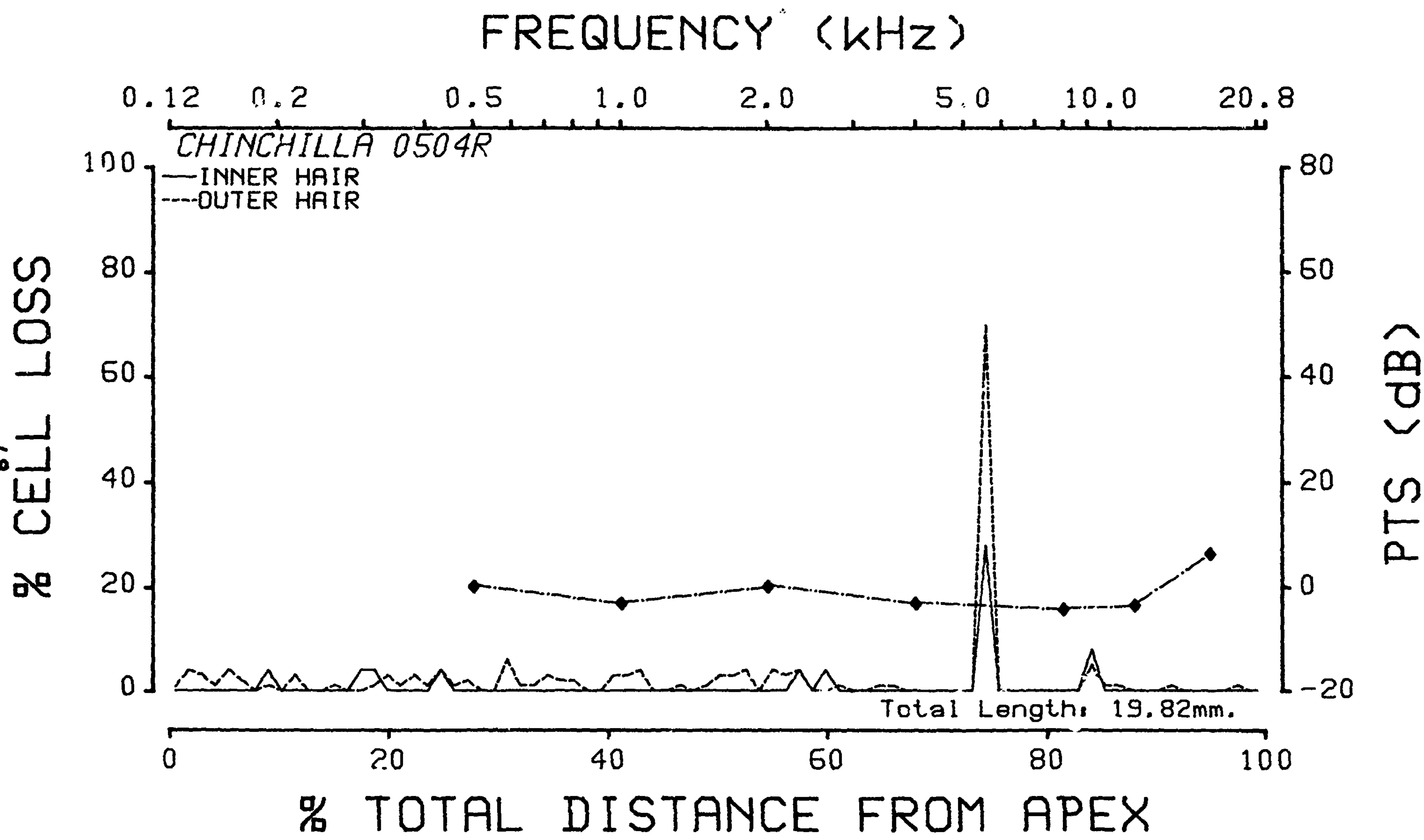
TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0507							
0.125 kHz	2	5	11	14	30	0	1
0.25 kHz	0	1	0	9	10	0	0
0.5 kHz	0	3	4	6	13	0	1
1 kHz	0	2	5	9	16	0	0
2 kHz	2	5	8	6	19	0	2
4 kHz	2	3	0	0	3	1	0
8 kHz	0	1	1	2	4	0	0
16 kHz	2	3	0	0	3	0	0
TOTALS	8	23	29	46	98	1	4
CHINCHILLA 0509							
0.125 kHz	1	7	7	28	42	0	1
0.25 kHz	5	5	9	35	49	0	0
0.5 kHz	2	10	30	18	58	0	0
1 kHz	7	15	44	14	73	1	1
2 kHz	3	10	17	6	33	1	1
4 kHz	22	31	31	37	99	20	11
8 kHz	4	7	7	12	26	0	0
16 kHz	3	6	7	5	18	0	0
TOTALS	47	91	152	155	398	22	14
GROUP MEANS							
0.125 kHz	1.0	10.6	18.8	29.0	58.4	0.0	1.4
0.25 kHz	2.6	1.8	8.6	42.6	53.0	0.0	0.0
0.5 kHz	1.2	4.0	11.0	22.4	37.4	0.0	0.6
1 kHz	1.8	6.6	17.0	12.0	35.6	0.2	0.8
2 kHz	2.2	7.0	7.4	4.6	19.0	0.2	1.8
4 kHz	5.4	9.4	8.8	11.0	29.2	5.0	3.6
8 kHz	2.0	5.0	5.6	6.8	17.4	0.8	1.8
16 kHz	1.4	3.0	2.8	1.6	7.4	0.0	0.2
TOTALS	17.6	47.4	80.0	130.0	257.4	6.2	10.2

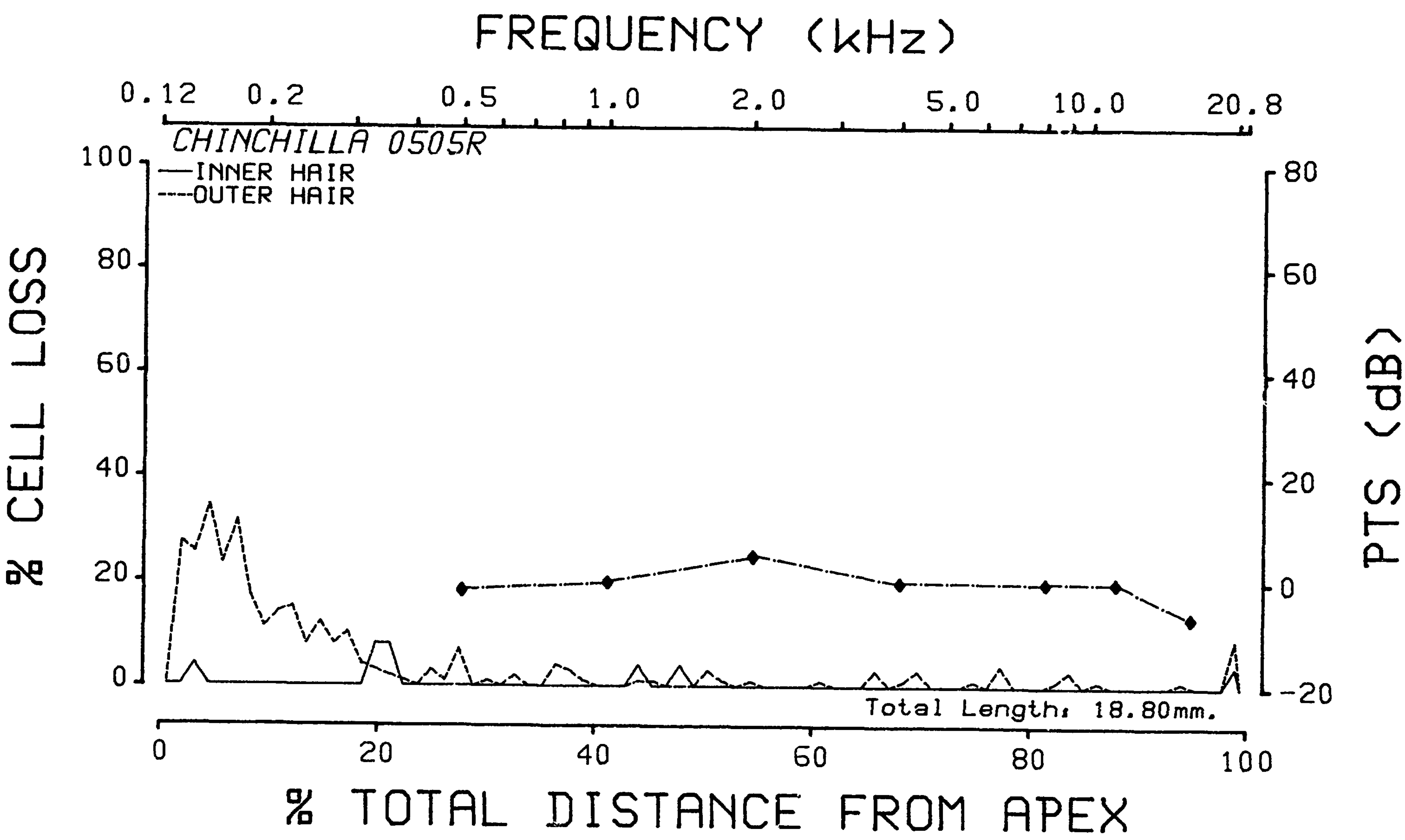
Cochleograms and PTS Audiograms

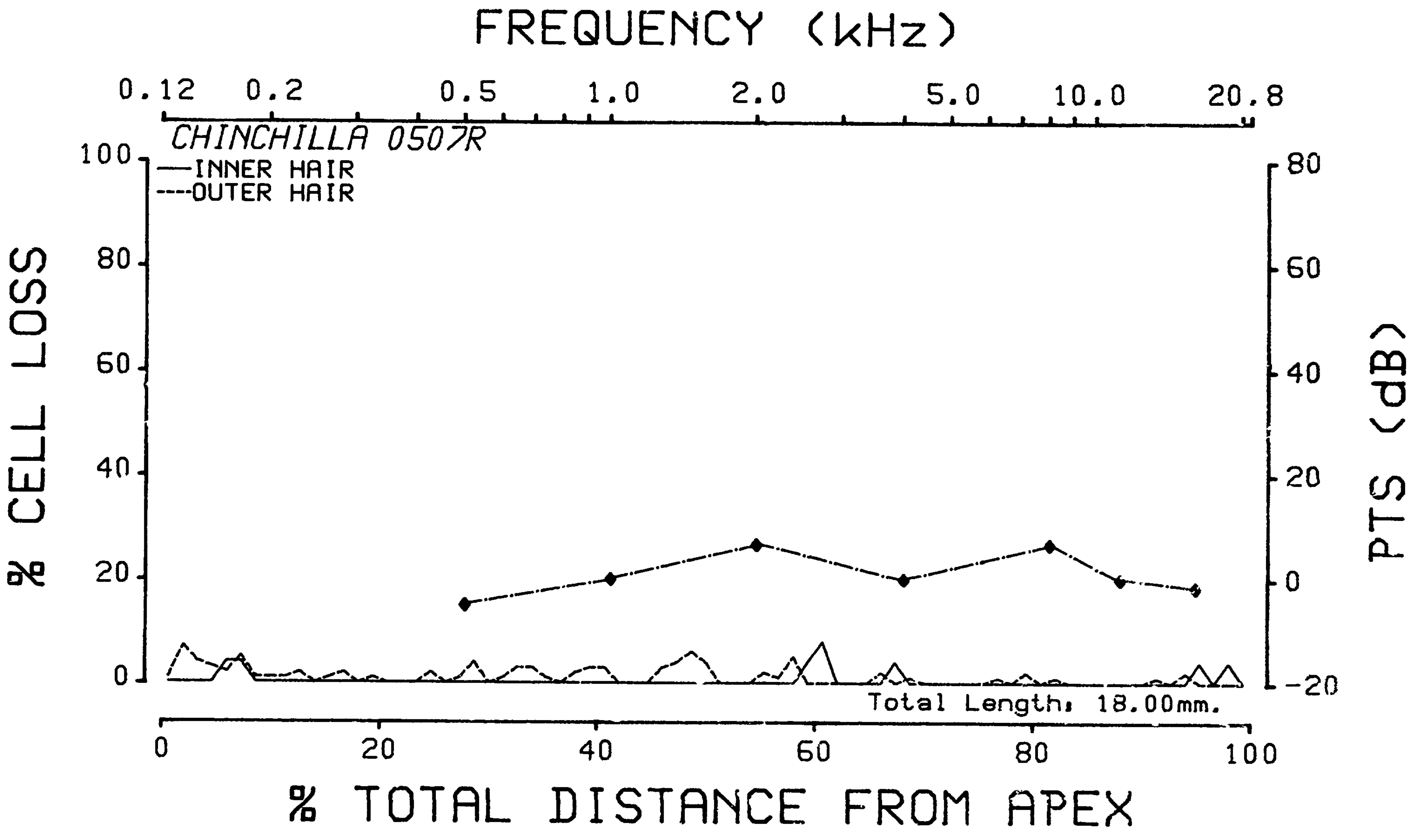
for Individual Animals

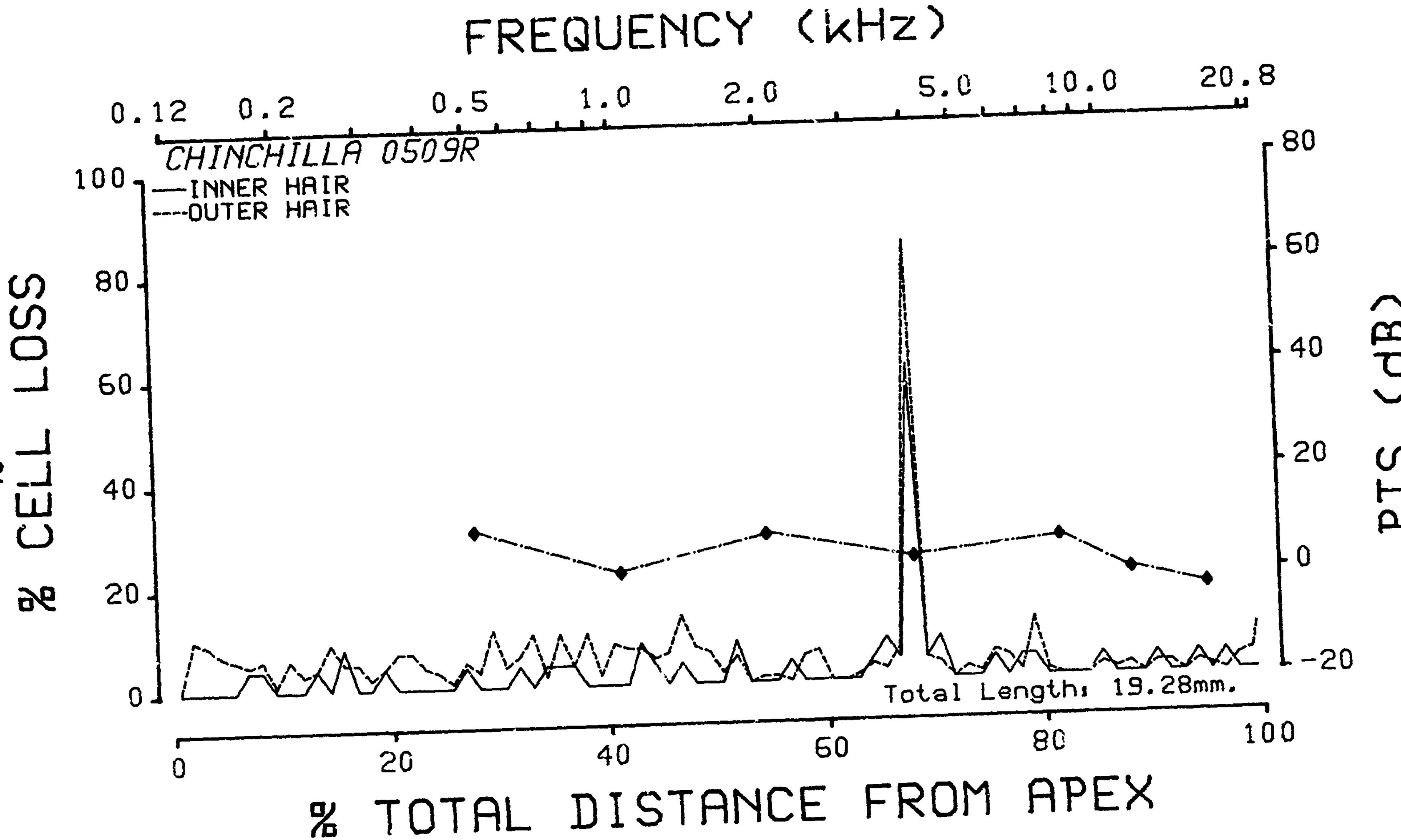

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0502R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.15mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0504R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 19.82mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0505R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.80mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0507R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.00mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0509R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 19.28mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

Summary Data for the Group Exposed to:

150 dB, 100X, 10/M

Animal #		
0525	-	Completed the Entire Protocol
0528	-	Completed the Entire Protocol
0530	-	Completed the Entire Protocol
0536	-	Completed the Entire Protocol
0538	-	Completed the Entire Protocol

150 dB 100X 10/M

PRE-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0525	19.2	5.8	10.8	4.2	24.2	22.5	29.2
0528	14.2	2.5	4.2	14.2	20.8	20.8	22.5
0530	19.2	5.8	20.8	9.2	14.2	22.5	22.5
0536	20.8	10.8	17.5	7.5	19.2	14.2	19.2
0538	19.2	2.5	9.2	-0.8	9.2	2.5	14.2
Mean	18.5	5.5	12.5	6.8	17.5	16.5	21.5
S.D.	2.5	3.4	6.7	5.6	5.9	8.6	5.5

POST-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0525	20.8	4.2	10.8	2.5	27.5	15.8	34.2
0528	19.2	5.8	17.5	20.8	35.8	24.2	20.8
0530	15.8	5.8	14.2	-2.5	12.5	22.5	15.8
0536	22.5	10.8	14.2	12.5	17.5	17.5	20.8
0538	24.2	5.8	7.5	-0.8	7.5	4.2	19.2
Mean	20.5	6.5	12.8	6.5	20.2	16.8	22.2
S.D.	3.2	2.5	3.8	9.9	11.5	7.9	7.0

PERMANENT THRESHOLD SHIFT (dB)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0525	1.7	-1.7	0.0	-1.7	3.3	-6.7	5.0
0528	5.0	3.3	13.3	6.7	15.0	3.3	-1.7
0530	-3.3	0.0	-6.7	-11.7	-1.7	0.0	-6.7
0536	1.7	0.0	-3.3	5.0	-1.7	3.3	1.7
0538	5.0	3.3	-1.7	0.0	-1.7	1.7	5.0
Mean	2.0	1.0	0.3	-0.3	2.7	0.3	0.7
S.D.	3.4	2.2	7.7	7.2	7.2	4.2	4.9

150 dB 100X 10/M

TEMPORARY THRESHOLD SHIFT (dB)

Frequency 0.5 kHz

Animal\Hr	0	2	8	24	240	Max
0525	28.3	-1.7	-1.7	3.3	8.3	28.3
0528	23.3	3.3	3.3	8.3	3.3	23.3
0530	13.3	3.3	3.3	-1.7	3.3	13.3
0536	36.7	6.7	1.7	1.7	1.7	36.7
0538	33.3	28.3	18.3	13.3	8.3	33.3
Mean	27.0	8.0	5.0	5.0	5.0	27.0
S.D.	9.2	11.8	7.7	5.9	3.1	9.2

Frequency 2.0 kHz

Animal\Hr	0	2	8	24	240	Max
0525	26.7	11.7	1.7	1.7	1.7	26.7
0528	63.3	23.3	23.3	28.3	18.3	63.3
0530	21.7	11.7	1.7	-3.3	-13.3	21.7
0536	30.0	10.0	0.0	-5.0	0.0	30.0
0538	53.3	23.3	8.3	3.3	-1.7	53.3
Mean	39.0	16.0	7.0	5.0	1.0	39.0
S.D.	18.2	6.7	9.7	13.5	11.3	18.2

Frequency 8.0 kHz

Animal\Hr	0	2	8	24	240	Max
0525	33.3	8.3	3.3	3.3	3.3	33.3
0528	51.7	31.7	26.7	31.7	21.7	51.7
0530	18.3	8.3	8.3	8.3	8.3	18.3
0536	23.3	-11.7	-1.7	-6.7	-6.7	23.3
0538	23.3	23.3	13.3	13.3	3.3	23.3
Mean	30.0	12.0	10.0	10.0	6.0	30.0
S.D.	13.3	16.6	10.9	14.2	10.3	13.3

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 10/M

Probe Frequency: 0.5 kHz

Masker (kHz):		0.150	0.200	0.300	0.400	0.520	0.600	0.650	0.750	1.300	2.200
Animal	(Q-10 dB)					Pre-Exposure					
0525	(3.19)	67.5	62.5	52.5	42.5	27.5	37.5	37.5	47.5	62.5	95.0*
0528	(1.75)	67.5	57.5	47.5	27.5	27.5	22.5	22.5	37.5	52.5	72.5
0530	(1.72)	72.5	67.5	57.5	47.5	42.5	37.5	42.5	47.5	67.5	95.0*
0536	(2.44)	67.5	57.5	52.5	42.5	27.5	27.5	37.5	42.5	77.5	95.0*
0538	(1.29)	72.5	62.5	52.5	42.5	37.5	42.5	42.5	47.5	87.5	95.0*
Mean	(2.08)	69.5	61.5	52.5	40.5	32.5	33.5	36.5	44.5	69.5	90.5
S.D.	(0.75)	2.7	4.2	3.5	7.6	7.1	8.2	8.2	4.5	13.5	10.1
Animal	(Q-10 dB)					Post-Exposure					
0525	(1.63)	72.5	62.5	52.5	47.5	42.5	42.5	42.5	37.5	77.5	95.0*
0528	(2.67)	67.5	67.5	57.5	47.5	37.5	32.5	37.5	52.5	82.5	95.0*
0530	(2.20)	72.5	62.5	72.5	52.5	37.5	32.5	37.5	42.5	67.5	95.0*
0536	(2.20)	67.5	67.5	57.5	42.5	37.5	47.5	37.5	42.5	95.0*	95.0*
0538	(1.72)	67.5	62.5	57.5	47.5	42.5	47.5	52.5	62.5	87.5	95.0*
Mean	(2.08)	69.5	64.5	59.5	47.5	39.5	40.5	41.5	47.5	82.0	95.0
S.D.	(0.42)	2.7	2.7	7.6	3.5	2.7	7.6	6.5	10.0	10.4	0.0

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 10/M

Probe Frequency: 1.0 kHz

Masker (kHz):		0.150	0.200	0.400	0.550	0.800	1.050	1.300	1.700	1.900	2.500
Animal	(Q-10 dB)					Pre-Exposure					
0525	(3.57)	77.5	72.5	62.5	52.5	37.5	17.5	32.5	47.5	57.5	82.5
0528	(4.17)	72.5	62.5	57.5	47.5	37.5	17.5	37.5	57.5	62.5	77.5
0530	(3.57)	82.5	72.5	67.5	62.5	37.5	17.5	32.5	67.5	82.5	91.0*
0536	(2.37)	82.5	72.5	67.5	52.5	42.5	22.5	27.5	57.5	97.5	91.0*
0538	(2.37)	82.5	72.5	57.5	42.5	37.5	17.5	22.5	52.5	67.5	91.0*
Mean	(3.21)	79.5	70.5	62.5	51.5	38.5	18.5	30.5	56.5	73.5	86.6
S.D.	(0.80)	4.5	4.5	5.0	7.4	2.2	2.2	5.7	7.4	16.4	6.3
Animal	(Q-10 dB)					Post-Exposure					
0525	(2.47)	67.5	72.5	52.5	37.5	37.5	22.5	32.5	47.5	62.5	67.5
0528	(4.17)	82.5	77.5	72.5	67.5	57.5	37.5	57.5	102.0*	92.0*	97.0*
0530	(3.13)	77.5	72.5	62.5	57.5	42.5	27.5	42.5	72.5	77.5	91.0*
0536	(1.47)	82.5	72.5	62.5	52.5	37.5	32.5	32.5	62.5	87.5	87.5
0538	(3.57)	77.5	67.5	52.5	47.5	37.5	17.5	32.5	52.5	52.5	87.5
Mean	(2.96)	77.5	72.5	60.5	52.5	42.5	27.5	39.5	67.4	74.4	86.1
S.D.	(1.04)	6.1	3.5	8.4	11.2	8.7	7.9	11.0	21.6	16.7	11.1

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 10/M

Probe Frequency: 2.0 kHz

Masker (kHz):		0.300	0.750	0.900	1.300	1.700	2.050	2.200	3.000	3.500	4.000
Animal	(Q-10 dB)					Pre-Exposure					
0525	(2.59)	77.5	47.5	42.5	42.5	37.5	27.5	27.5	52.5	57.5	72.5
0528	(2.15)	82.5	42.5	42.5	37.5	12.5	12.5	17.5	47.5	57.5	82.5
0530	(2.04)	87.5	67.5	47.5	52.5	42.5	37.5	37.5	62.5	87.0*	96.0*
0536	(3.24)	92.5	57.5	57.5	52.5	42.5	37.5	32.5	72.5	87.0*	96.0*
0538	(2.42)	77.5	47.5	42.5	37.5	32.5	27.5	42.5	62.5	72.5	96.0*
Mean	(2.49)	83.5	52.5	46.5	44.5	33.5	28.5	31.5	59.5	72.3	88.6
S.D.	(0.47)	6.5	10.0	6.5	7.6	12.4	10.2	9.6	9.7	14.8	10.7
Animal	(Q-10 dB)					Post-Exposure					
0525	(4.57)	72.5	47.5	47.5	37.5	32.5	22.5	37.5	47.5	57.5	72.5
0528	(3.58)	72.5	57.5	47.5	62.5	57.5	37.5	37.5	67.5	87.0*	96.0*
0530	(1.89)	77.5	67.5	42.5	52.5	42.5	37.5	37.5	57.5	87.0*	96.0*
0536	(2.08)	82.5	62.5	47.5	37.5	32.5	27.5	32.5	72.5	67.5	96.0*
0538	(6.14)	77.5	47.5	37.5	32.5	42.5	22.5	32.5	52.5	77.5	96.0*
Mean	(3.65)	76.5	56.5	44.5	44.5	41.5	29.5	35.5	59.5	75.3	91.3
S.D.	(1.77)	4.2	8.9	4.5	12.5	10.2	7.6	2.7	10.4	12.8	10.5

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 10/M

Probe Frequency: 4.0 kHz

Masker (kHz):		0.450	1.300	2.200	3.000	3.500	4.100	4.500	5.000	5.600	6.000
Animal	(Q-10 dB)					Pre-Exposure					
0525	(2.89)	62.5	57.5	52.5	42.5	17.5	17.5	27.5	37.5	52.5	62.5
0528	(6.09)	77.5	57.5	47.5	52.5	32.5	17.5	32.5	37.5	57.5	92.0*
0530	(4.10)	82.5	57.5	57.5	52.5	32.5	22.5	32.5	52.5	67.5	92.0*
0536	(3.24)	77.5	52.5	52.5	52.5	27.5	22.5	27.5	42.5	72.5	92.0*
0538	(5.06)	72.5	47.5	47.5	52.5	27.5	12.5	22.5	42.5	62.5	82.5
Mean	(4.28)	74.5	54.5	51.5	50.5	27.5	18.5	28.5	42.5	62.5	84.2
S.D.	(1.32)	7.6	4.5	4.2	4.5	6.1	4.2	4.2	6.1	7.9	12.8
Animal	(Q-10 dB)					Post-Exposure					
0525	(6.30)	67.5	47.5	42.5	47.5	37.5	12.5	22.5	37.5	42.5	67.5
0528	(6.09)	82.5	57.5	62.5	62.5	47.5	32.5	47.5	57.5	77.5	87.5
0530	(6.09)	72.5	47.5	47.5	42.5	22.5	7.5	22.5	32.5	42.5	67.5
0536	(4.76)	77.5	57.5	52.5	57.5	32.5	22.5	37.5	47.5	72.5	92.0*
0538	(3.30)	67.5	42.5	47.5	47.5	32.5	22.5	22.5	42.5	57.5	77.5
Mean	(5.31)	73.5	50.5	50.5	51.5	34.5	19.5	30.5	43.5	58.5	78.4
S.D.	(1.28)	6.5	6.7	7.6	8.2	9.1	9.7	11.5	9.6	16.4	11.2

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 1C/M

Probe Frequency: 8.0 kHz

Masker (kHz):		0.450	1.300	2.500	5.900	7.000	8.100	9.300	11.000	12.700	14.000
Animal	(Q-10 dB)					Pre-Exposure					
0525	(6.53)	72.5	62.5	57.5	37.5	47.5	22.5	37.5	52.5	82.5	95.0*
0528	(3.16)	82.5	57.5	62.5	42.5	37.5	27.5	32.5	62.5	67.5	72.5
0530	(5.29)	72.5	47.5	47.5	42.5	32.5	17.5	32.5	52.5	72.5	87.5
0536	(2.72)	77.5	62.5	57.5	42.5	37.5	32.5	47.5	57.5	97.0*	95.0*
0538	(1.07)	77.5	52.5	52.5	37.5	32.5	32.5	32.5	42.5	77.5	92.5
Mean	(3.75)	76.5	56.5	55.5	40.5	37.5	26.5	36.5	53.5	79.4	88.5
S.D.	(2.16)	4.2	6.5	5.7	2.7	6.1	6.5	6.5	7.4	11.3	9.5
Animal	(Q-10 dB)					Post-Exposure					
0525	(3.98)	82.5	72.5	62.5	57.5	52.5	32.5	37.5	67.5	97.5	95.0*
0528	(3.52)	87.5	62.5	62.5	57.5	57.5	47.5	57.5	102.0*	100.0*	95.0*
0530	(5.29)	87.5	62.5	62.5	32.5	37.5	22.5	37.5	67.5	87.5	95.0*
0536	(4.58)	82.5	62.5	62.5	47.5	47.5	27.5	37.5	52.5	87.5	92.5
0538	(3.73)	72.5	57.5	57.5	42.5	47.5	27.5	32.5	52.5	67.5	92.5
Mean	(4.22)	82.5	63.5	61.5	47.5	48.5	31.5	40.5	68.4	88.0	94.0
S.D.	(0.72)	6.1	5.5	2.2	10.6	7.4	9.6	9.7	20.2	12.8	1.4

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 10/M

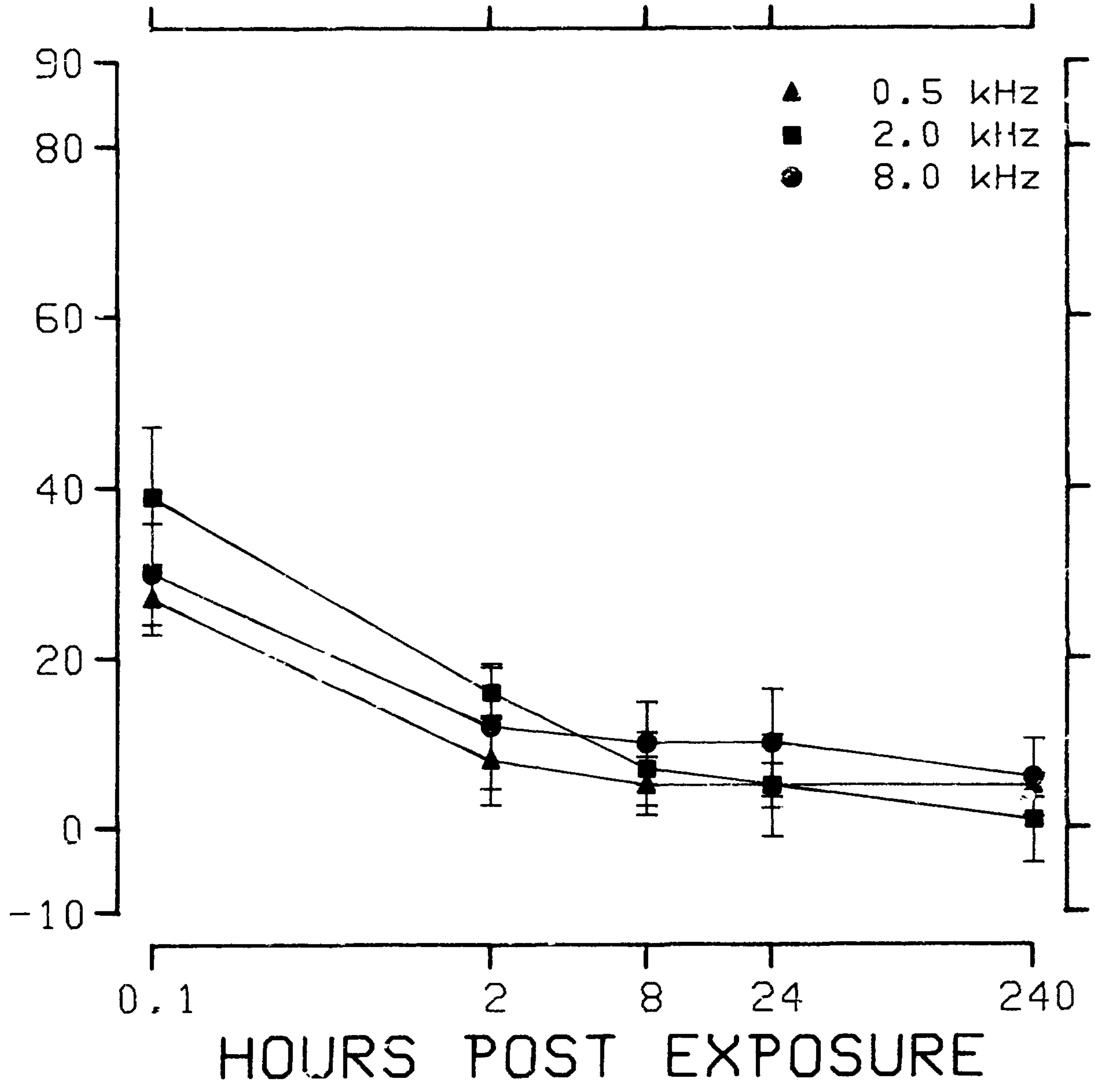
Probe Frequency: 11.2 kHz

Masker (kHz):		1.000	4.000	7.000	9.000	11.000	11.500	12.000	13.000	14.500	16.000
Animal	(Q-10 dB)					Pre-Exposure					
0525	(3.62)	72.5	62.5	72.5	57.5	42.5	42.5	42.5	57.5	62.5	87.5
0528	(11.48)	62.5	57.5	67.5	47.5	37.5	27.5	37.5	42.5	57.5	77.5
0530	(5.36)	67.5	57.5	57.5	57.5	37.5	42.5	47.5	47.5	77.5	91.0*
0536	(5.00)	72.5	62.5	62.5	62.5	32.5	32.5	37.5	47.5	57.5	82.5
0538	(4.06)	62.5	57.5	62.5	52.5	22.5	27.5	27.5	32.5	52.5	72.5
Mean	(5.90)	67.5	59.5	64.5	55.5	34.5	34.5	38.5	45.5	61.5	82.2
S.D.	(3.19)	5.0	2.7	5.7	5.7	7.6	7.6	7.4	9.1	9.6	7.4
Animal	(Q-10 dB)					Post-Exposure					
0525	(3.77)	72.5	57.5	67.5	57.5	47.5	42.5	47.5	52.5	72.5	82.5
0528	(10.55)	67.5	57.5	72.5	62.5	32.5	47.5	47.5	67.5	72.5	91.0*
0530	(7.70)	57.5	52.5	52.5	47.5	52.5	37.5	37.5	52.5	72.5	91.0*
0536	(3.67)	62.5	62.5	62.5	67.5	37.5	42.5	37.5	42.5	67.5	91.0*
0538	(4.73)	67.5	62.5	57.5	57.5	32.5	27.5	32.5	37.5	57.5	82.5
Mean	(6.08)	65.5	58.5	62.5	58.5	40.5	39.5	40.5	50.5	68.5	87.6
S.D.	(2.98)	5.7	4.2	7.9	7.4	9.1	7.6	6.7	11.5	6.5	4.7

The Group Mean Recovery Curves

Measured at Three Test Frequencies

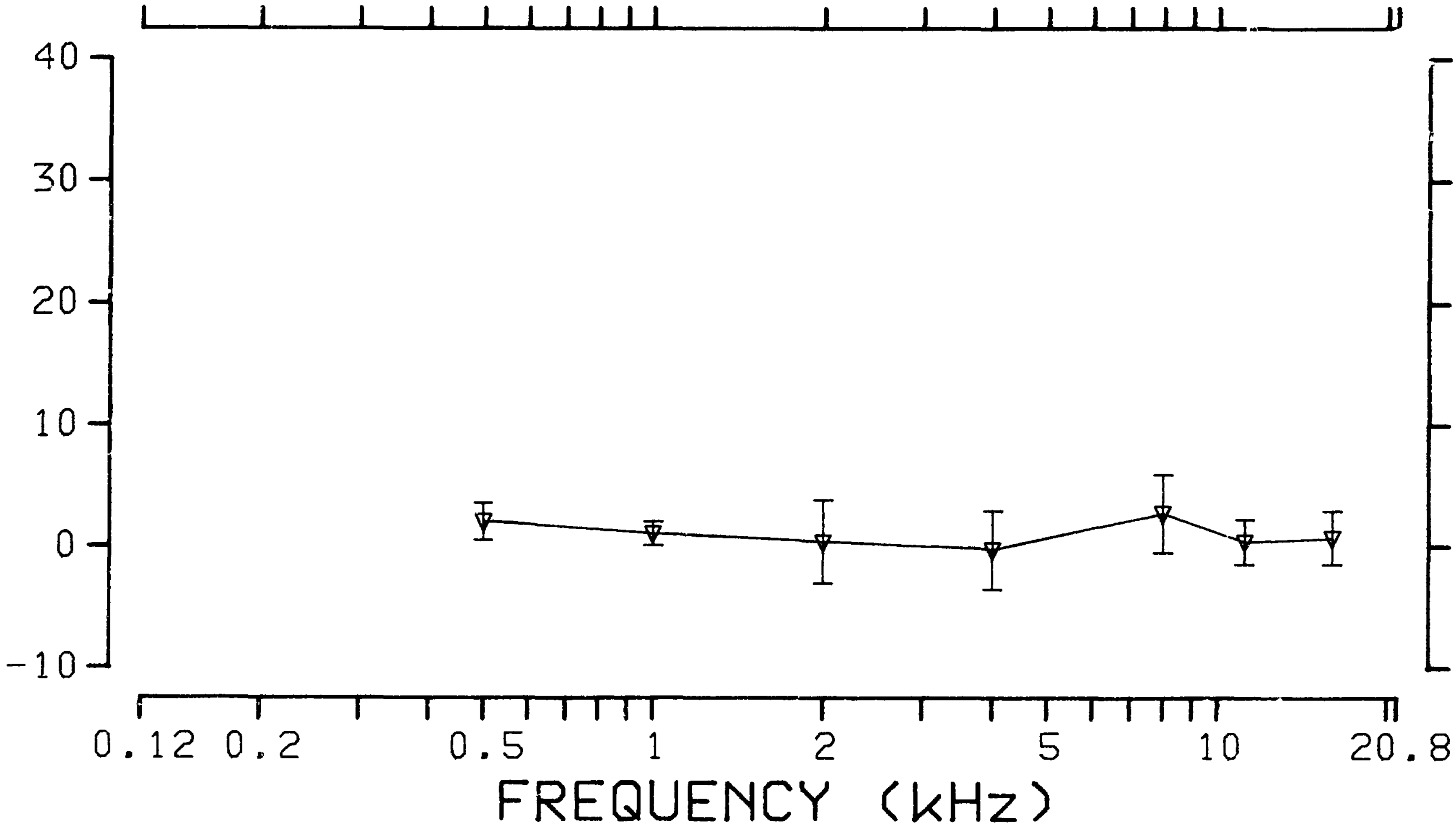
MEAN DATA (n=5) - 150 dB 100X 10/M



The Group Mean Permanent Threshold Shift (PTS)

for all Test Frequencies

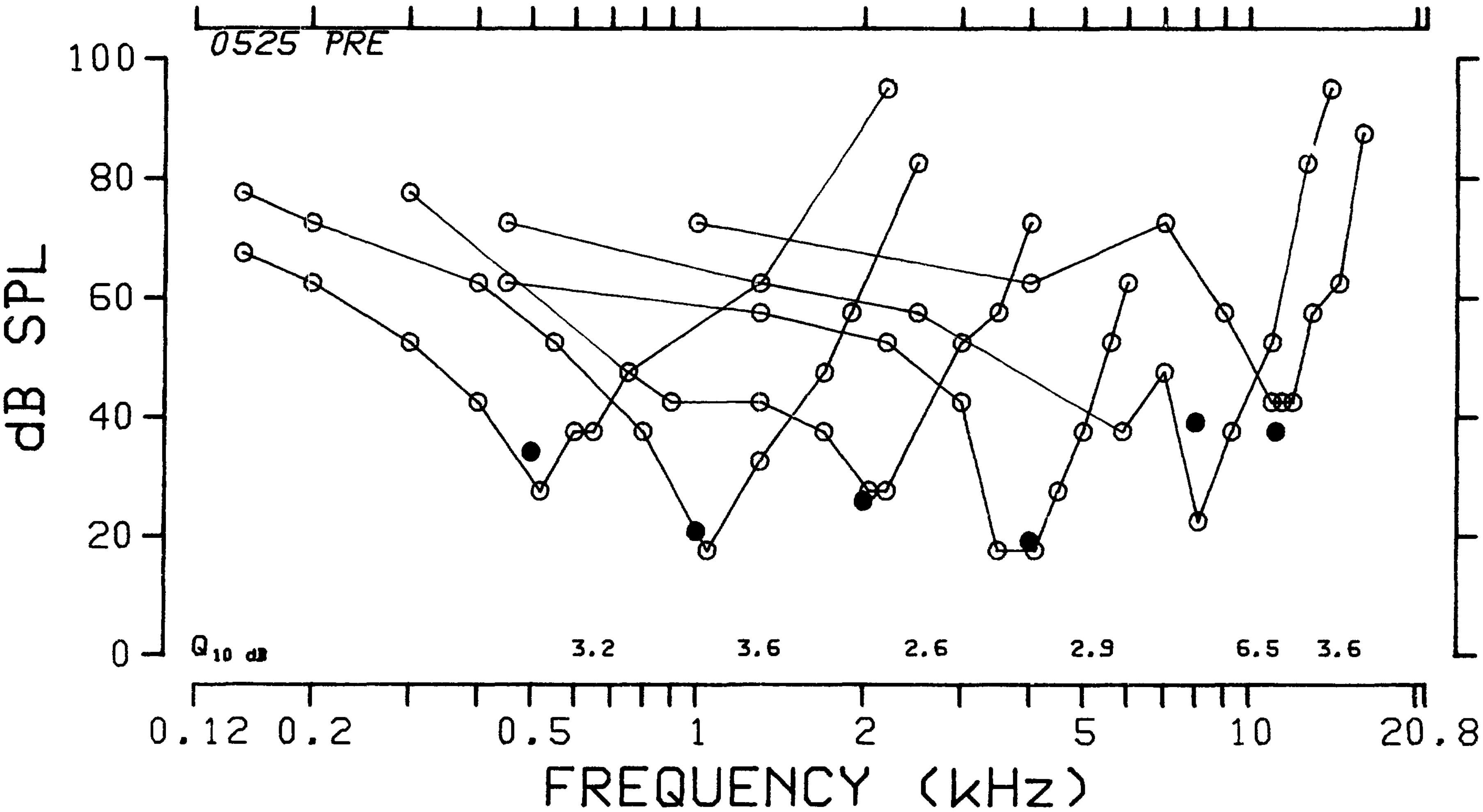
MEAN DATA (n=5) - 150 dB 100X 10/M

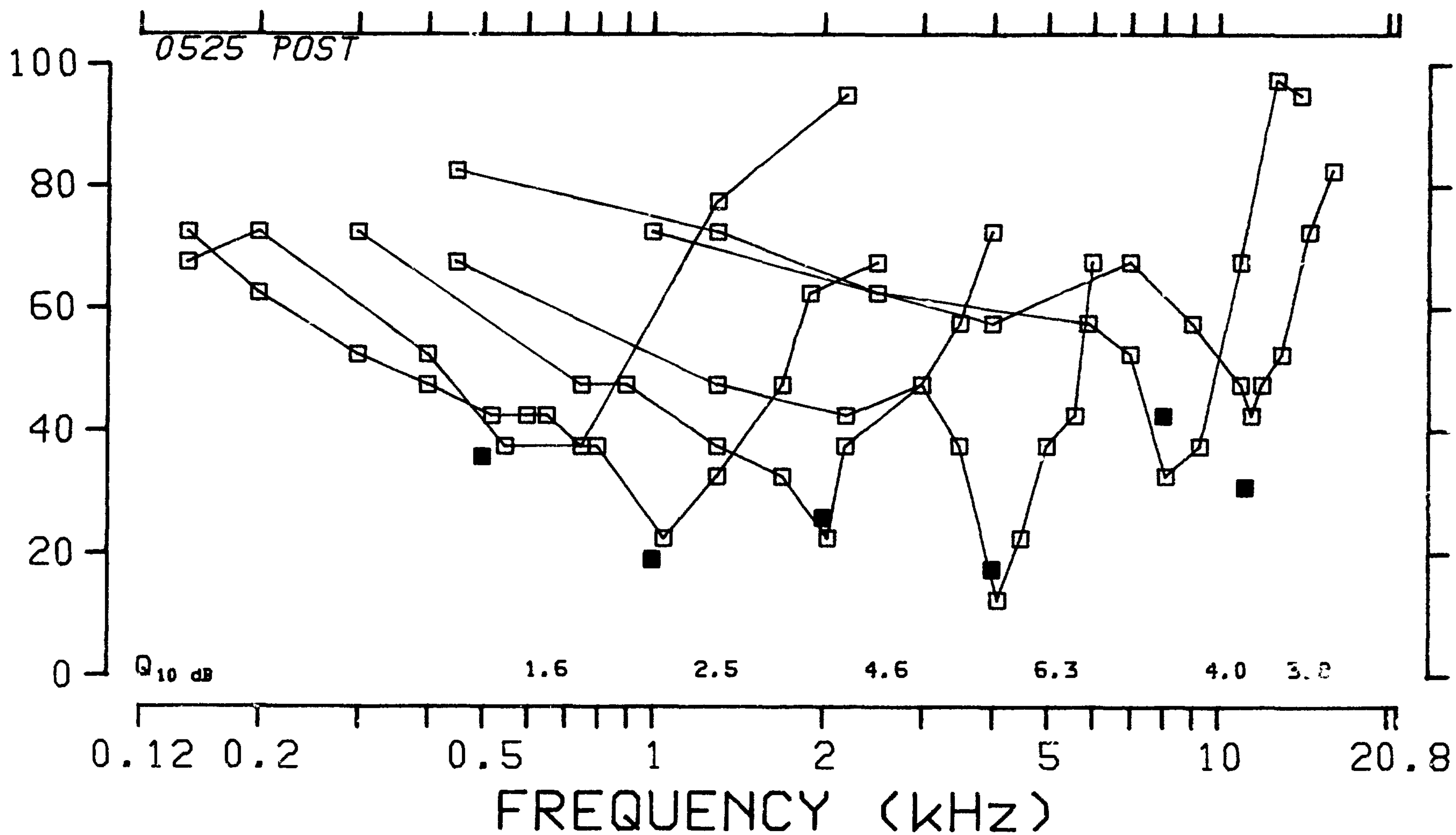


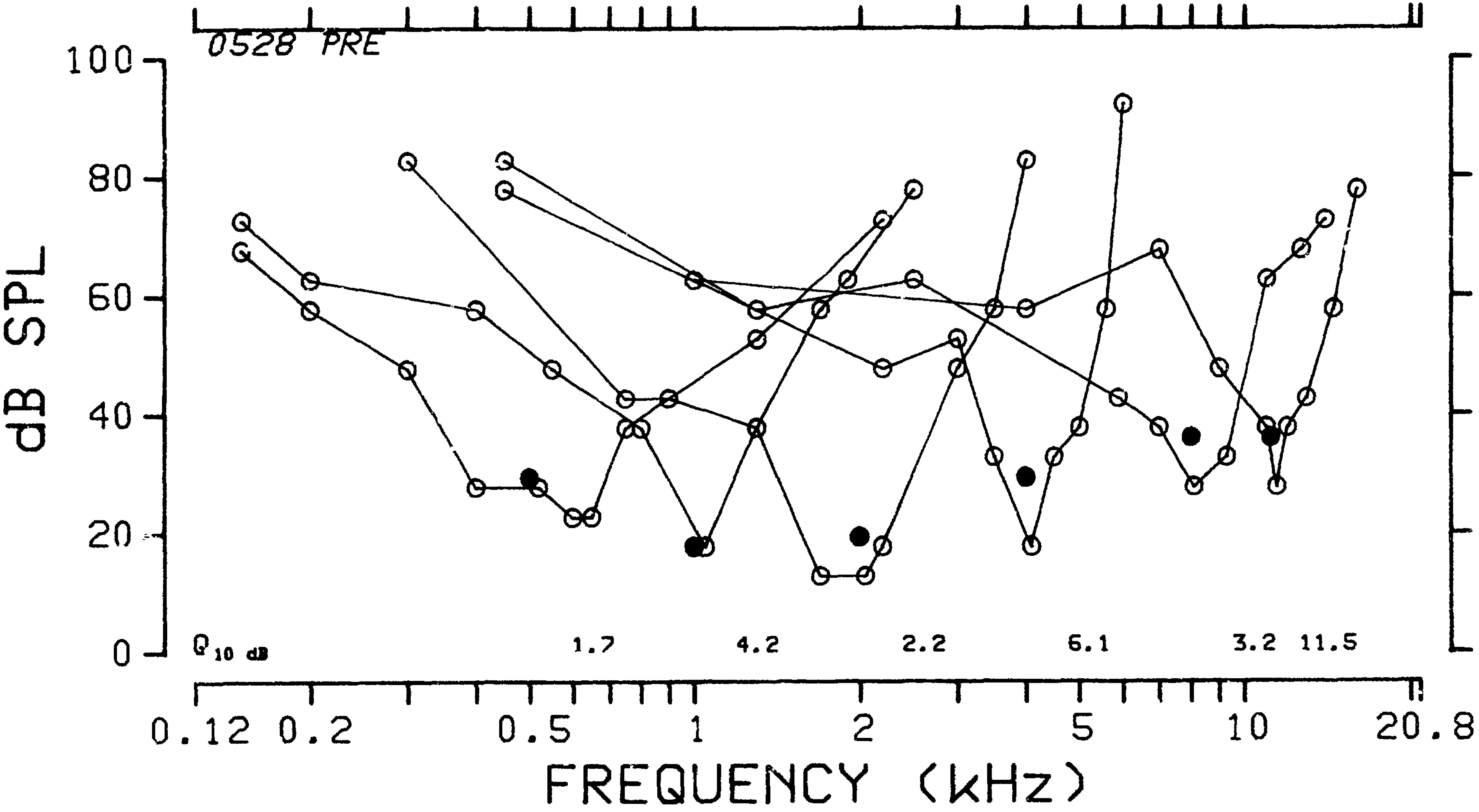
The Pre and Postexposure Tuning Curves for

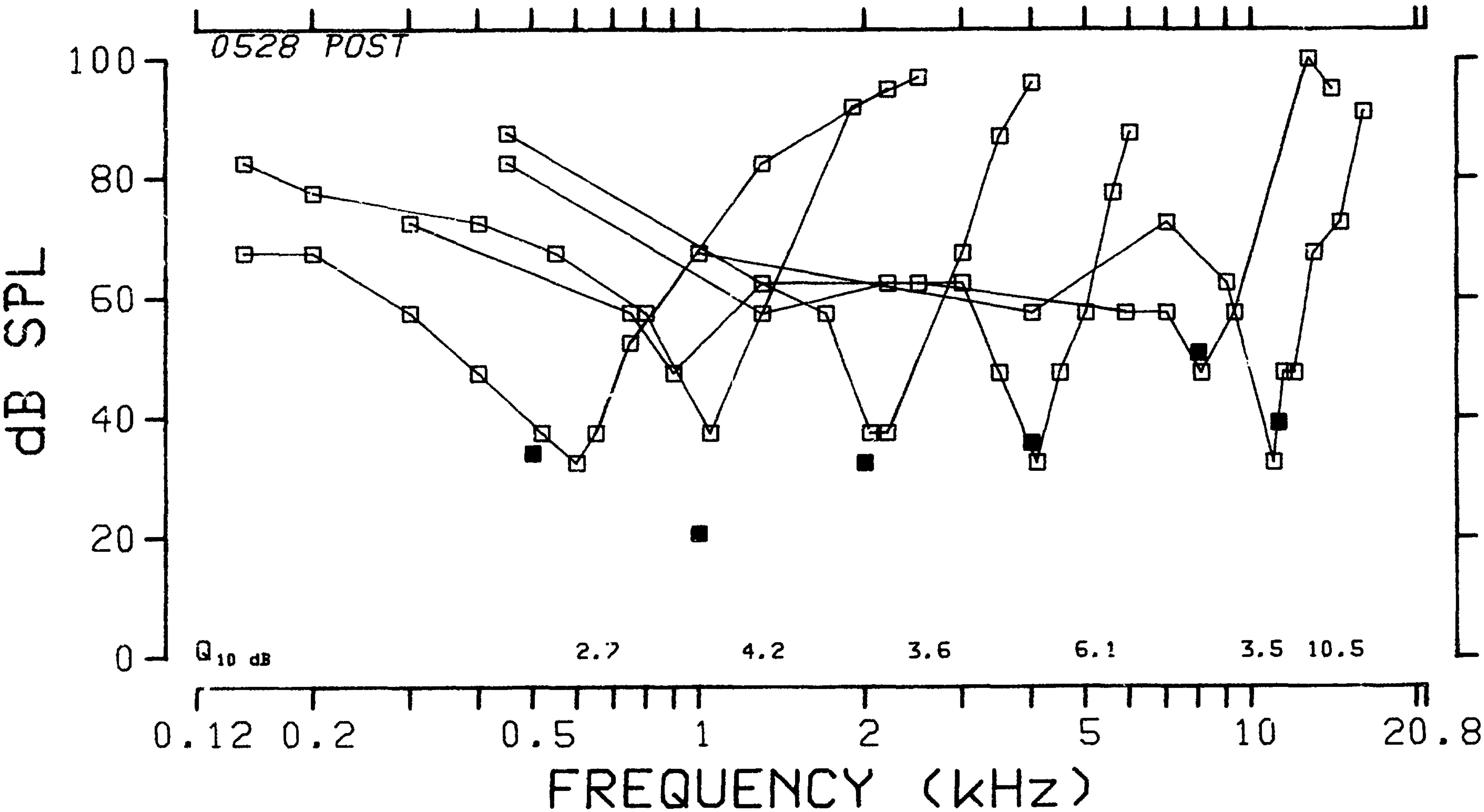
Individual Animals in this Exposure Group.

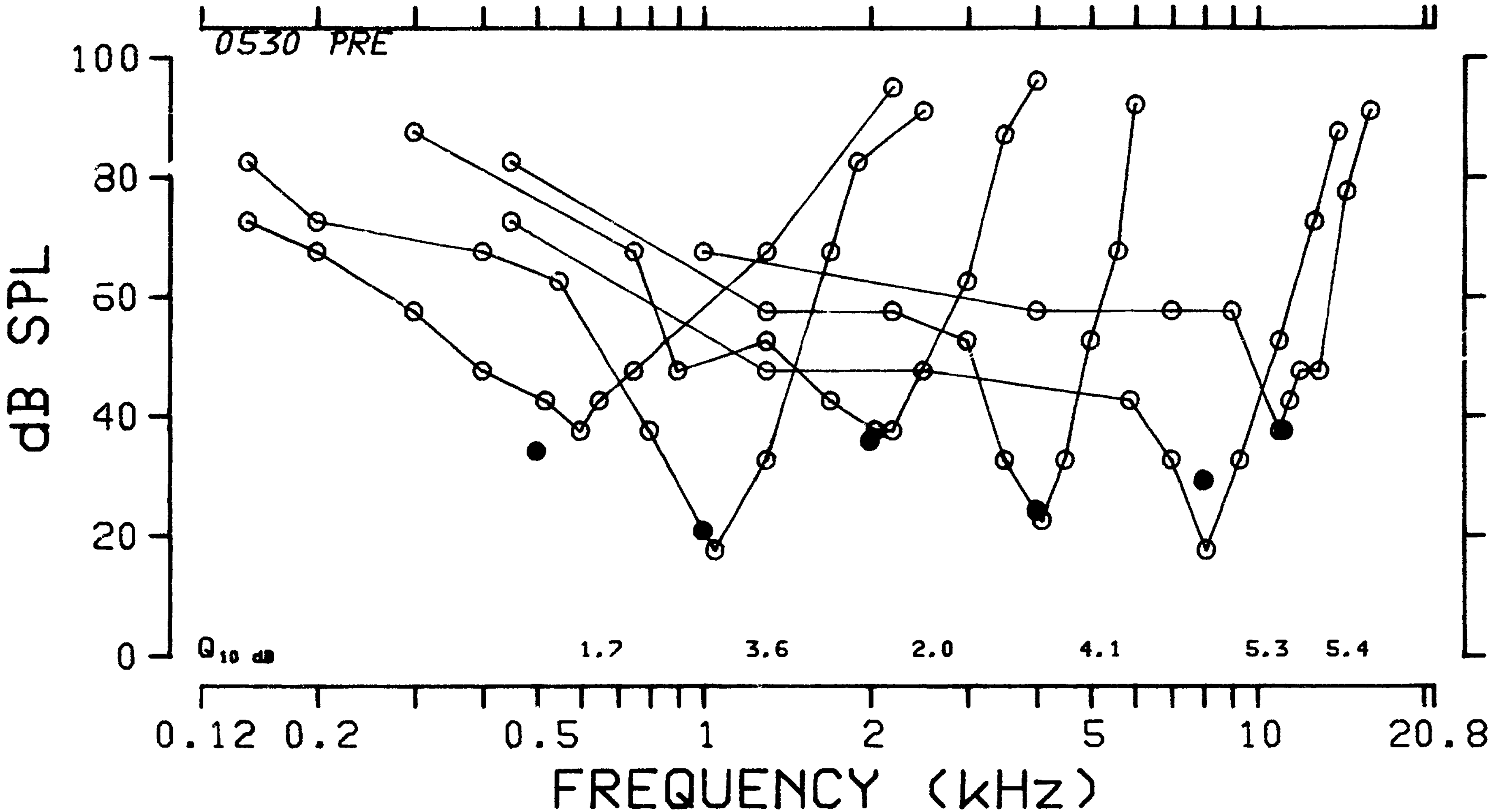
The Solid Symbol represents the intensity of the probe tone.

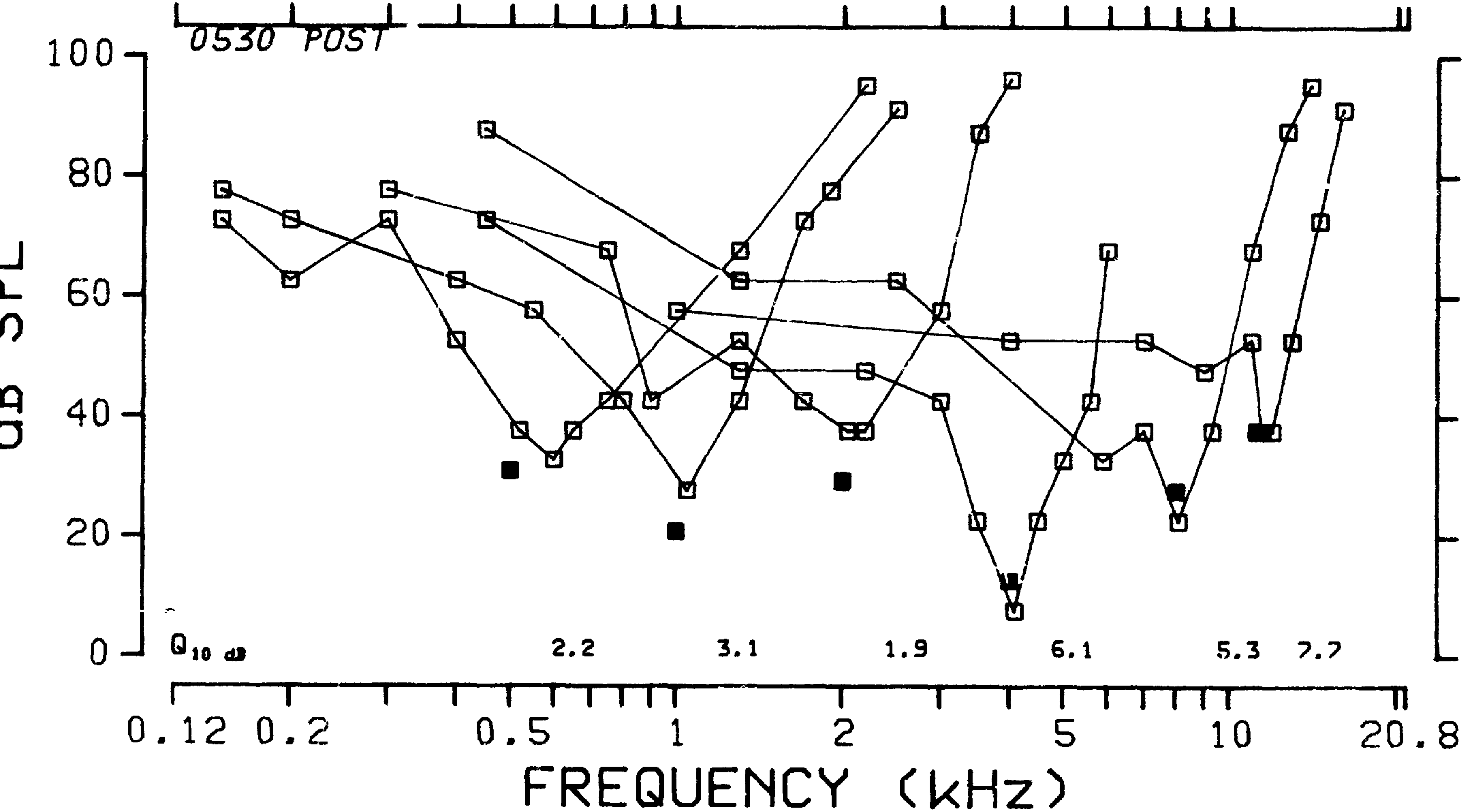

0525 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
3.2
3.6
2.6
2.9
6.5
3.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0525 POST
100
80
60
40
20
0
dB SPL
$Q_{10\ dB}$
1.6
2.5
4.6
6.3
4.0
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

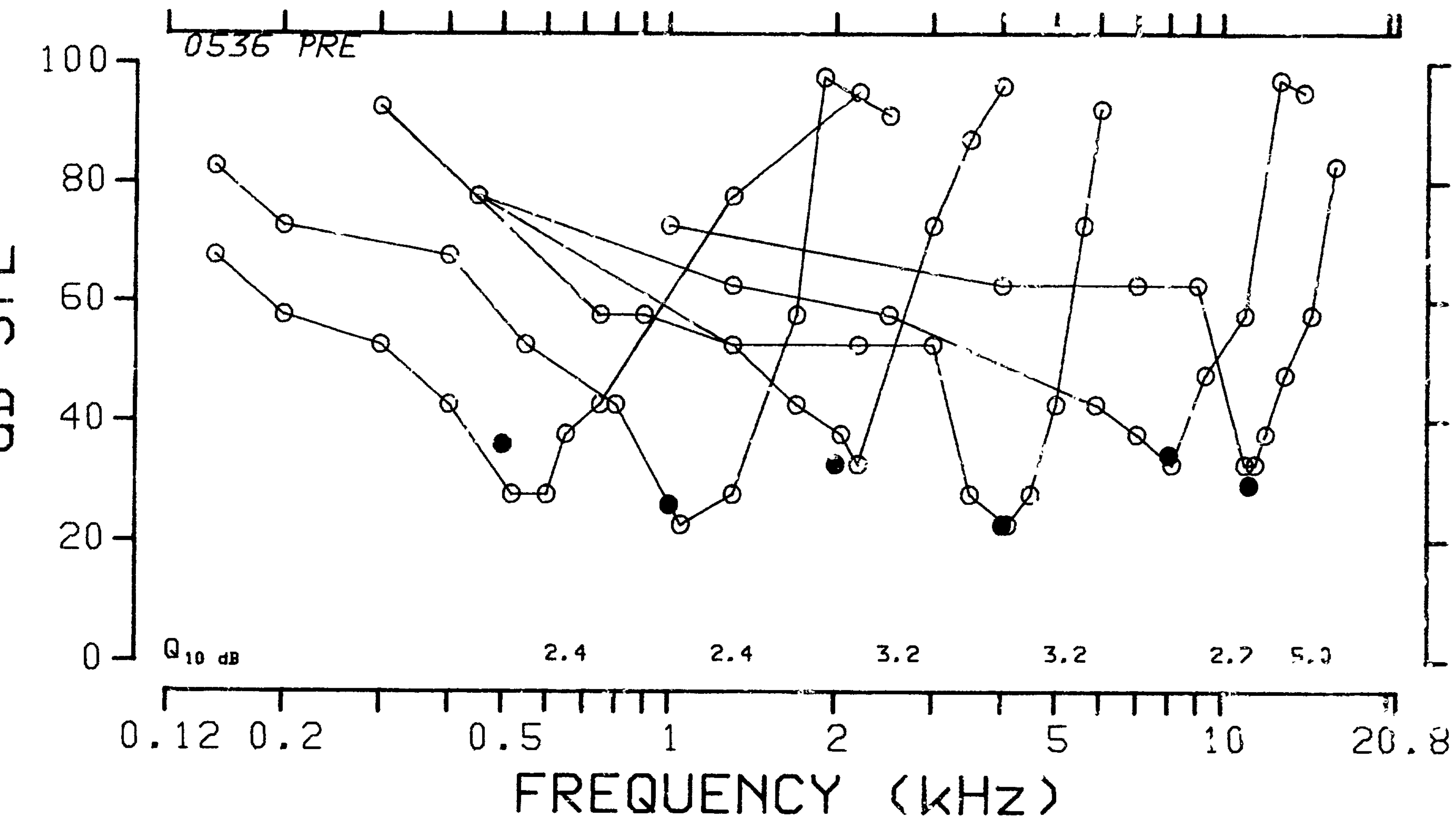

0528 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.7
4.2
2.2
6.1
3.2
11.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0528 POST
dB SPL
100
80
60
40
20
0
Q10 dB
2.7
4.2
3.6
6.1
3.5
10.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

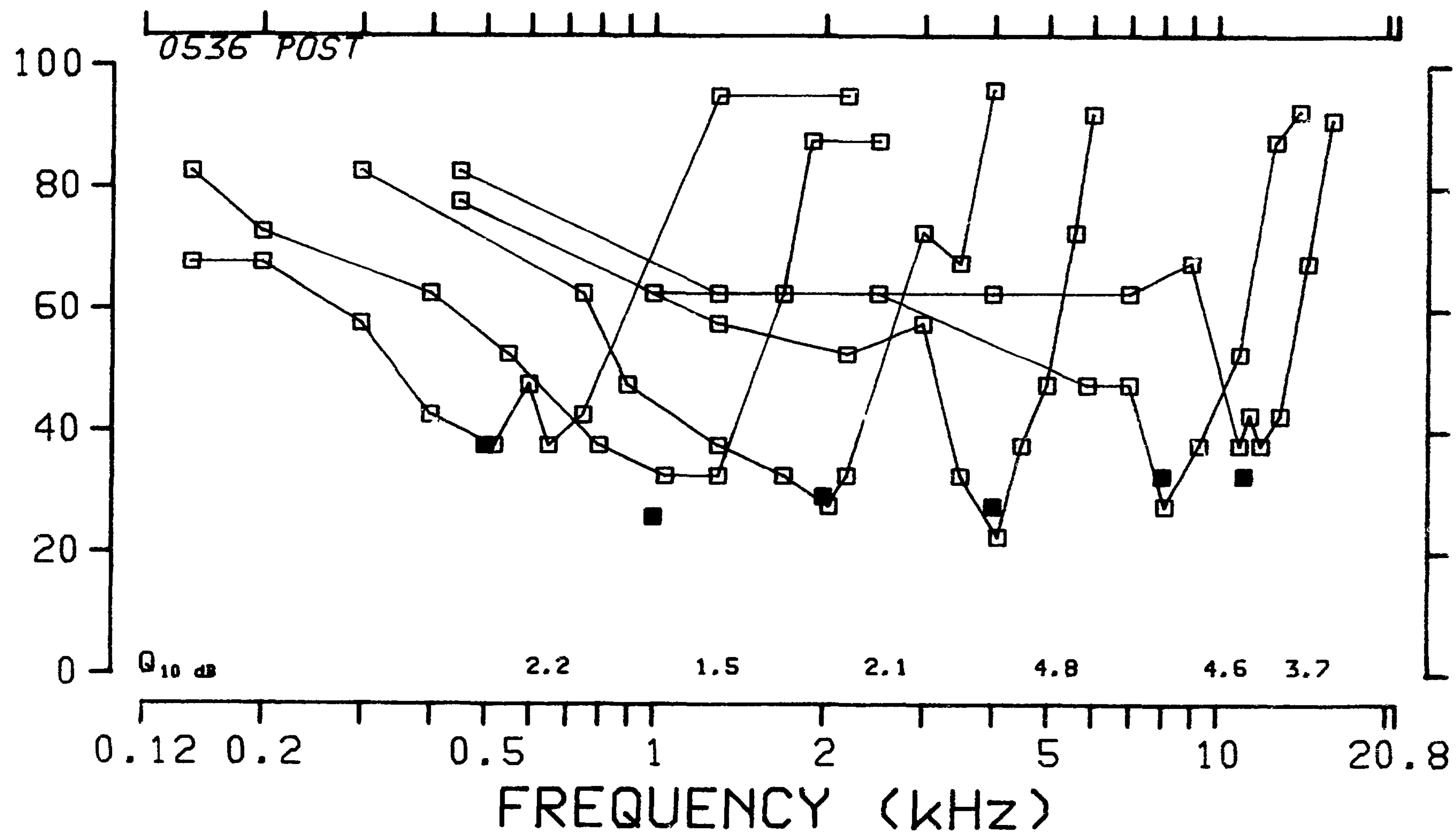

0530 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.7
3.6
2.0
4.1
5.3
5.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

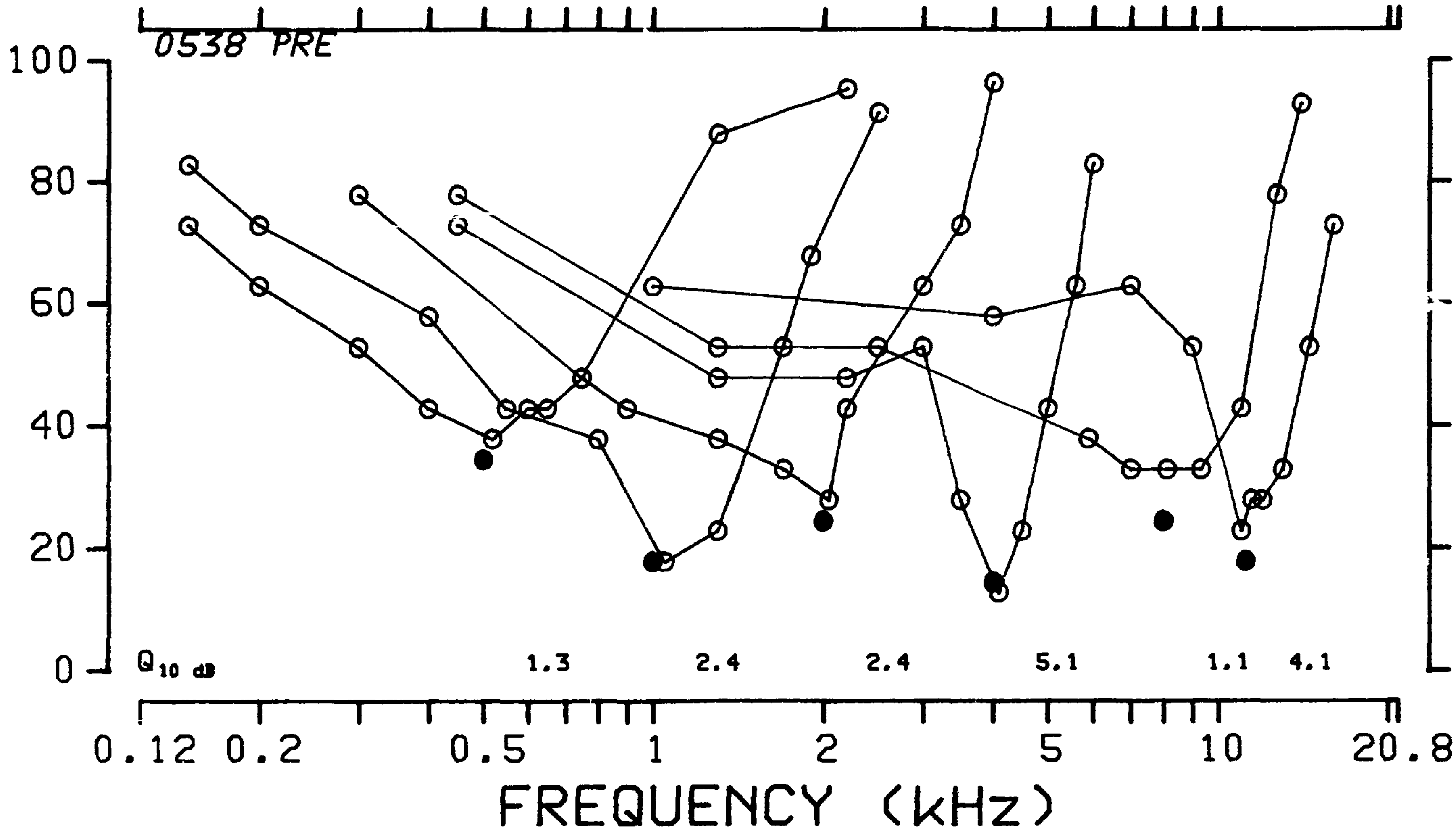

0530 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.2
3.1
1.9
6.1
5.3
7.7
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

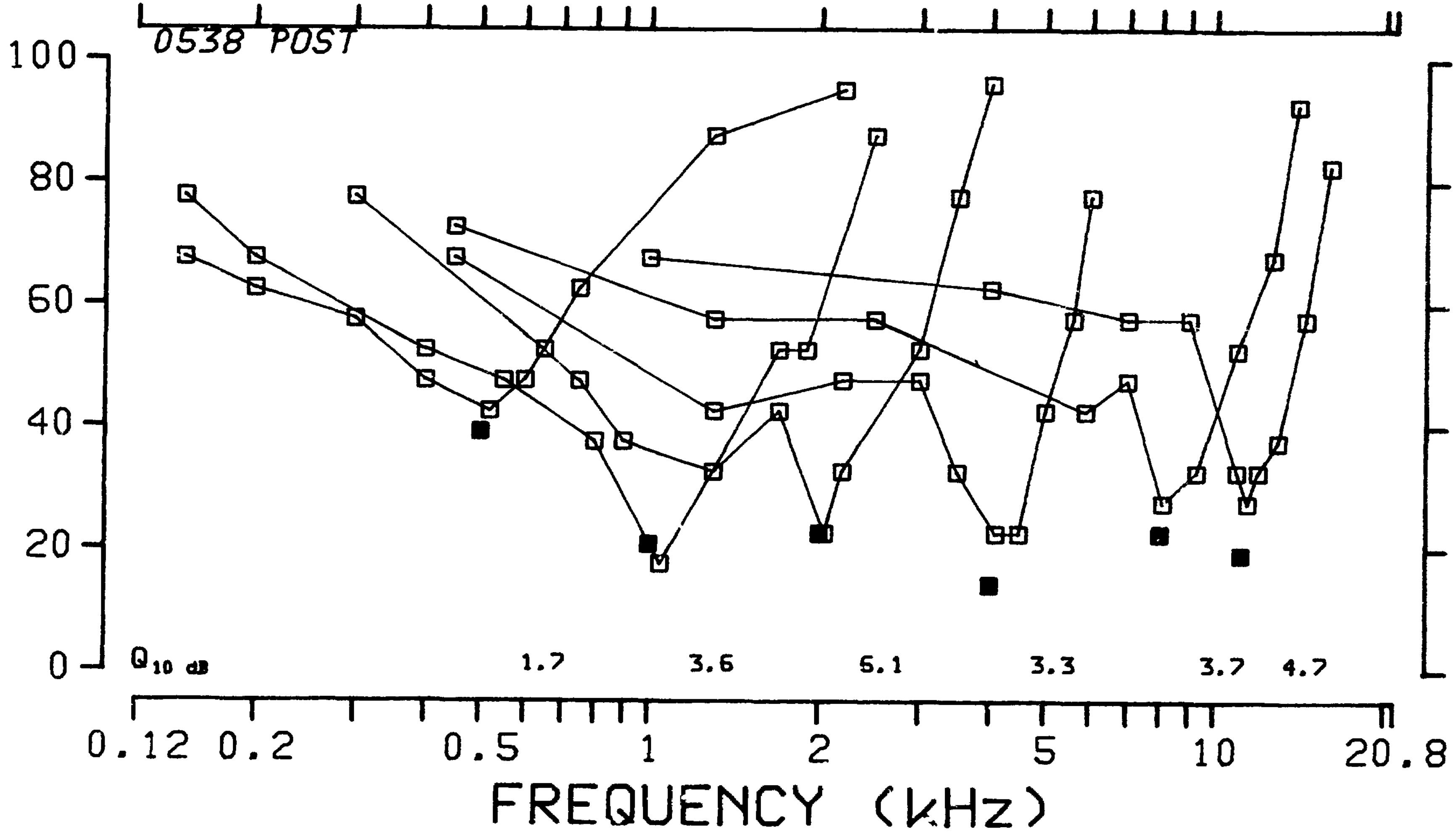
16


0536 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.4
2.4
3.2
3.2
2.7
5.0
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

92


0536 POST
100
80
60
40
20
0
dB SPL
$Q_{10\ dB}$
2.2
1.5
2.1
4.8
4.6
3.7
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0538 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.3
2.4
2.4
5.1
1.1
4.1
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0538 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.7
3.6
5.1
3.3
3.7
4.7
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

150 dB 100X 10/M

TOTAL NUMBER OF COCHLEAR SENSORY CELLS MISSING

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0525	5	45	69	55	169
0528	12	39	39	108	186
0530	12	40	35	131	206
0536	11	8	8	45	61
0538	2	75	48	111	234
GROUP MEAN	8				171
S.D.	5				66
S.E.	2				30

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

	OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	OUTER HAIR CELLS
GROUP MEANS			
	0.125 kHz	1.8	43.8
	0.25 kHz	1.2	39.4
	0.5 kHz	1.0	25.8
	1 kHz	1.4	13.2
	2 kHz	1.0	6.6
	4 kHz	1.4	8.6
	8 kHz	0.4	11.2
	16 kHz	0.2	22.6
STANDARD DEVIATIONS			
	0.125 kHz	1.1	18.3
	0.25 kHz	0.8	25.8
	0.5 kHz	0.7	16.9
	1 kHz	1.7	7.4
	2 kHz	1.7	2.3
	4 kHz	1.5	5.3
	8 kHz	0.5	7.7
	16 kHz	0.4	19.4

150 dB 100X 10/M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0525							
0.125 kHz	1	6	13	15	34	0	0
0.25 kHz	0	1	4	8	13	0	0
0.5 kHz	1	1	16	2	19	0	0
1 kHz	2	2	6	2	10	1	0
2 kHz	0	5	3	0	8	0	0
4 kHz	1	2	5	3	10	0	0
8 kHz	0	2	8	11	21	0	0
16 kHz	0	26	14	14	54	0	1
TOTALS	5	45	69	55	169	1	1
CHINCHILLA 0528							
0.125 kHz	3	9	19	43	71	0	3
0.25 kHz	1	7	5	29	41	0	4
0.5 kHz	2	3	0	15	18	1	0
1 kHz	0	5	4	5	14	0	0
2 kHz	4	3	1	2	6	0	0
4 kHz	1	5	3	0	8	0	1
8 kHz	1	2	3	5	10	1	0
16 kHz	0	5	4	9	18	0	0
TOTALS	12	39	39	108	186	2	8
CHINCHILLA 0530							
0.125 kHz	3	7	15	31	53	0	0
0.25 kHz	2	12	3	55	70	0	0
0.5 kHz	1	4	4	24	32	0	0
1 kHz	1	1	2	9	12	0	0
2 kHz	0	1	1	1	3	0	0
4 kHz	4	3	4	4	11	0	0
8 kHz	0	4	1	3	8	0	0
16 kHz	1	8	5	4	17	0	1
TOTALS	12	40	35	131	206	0	1

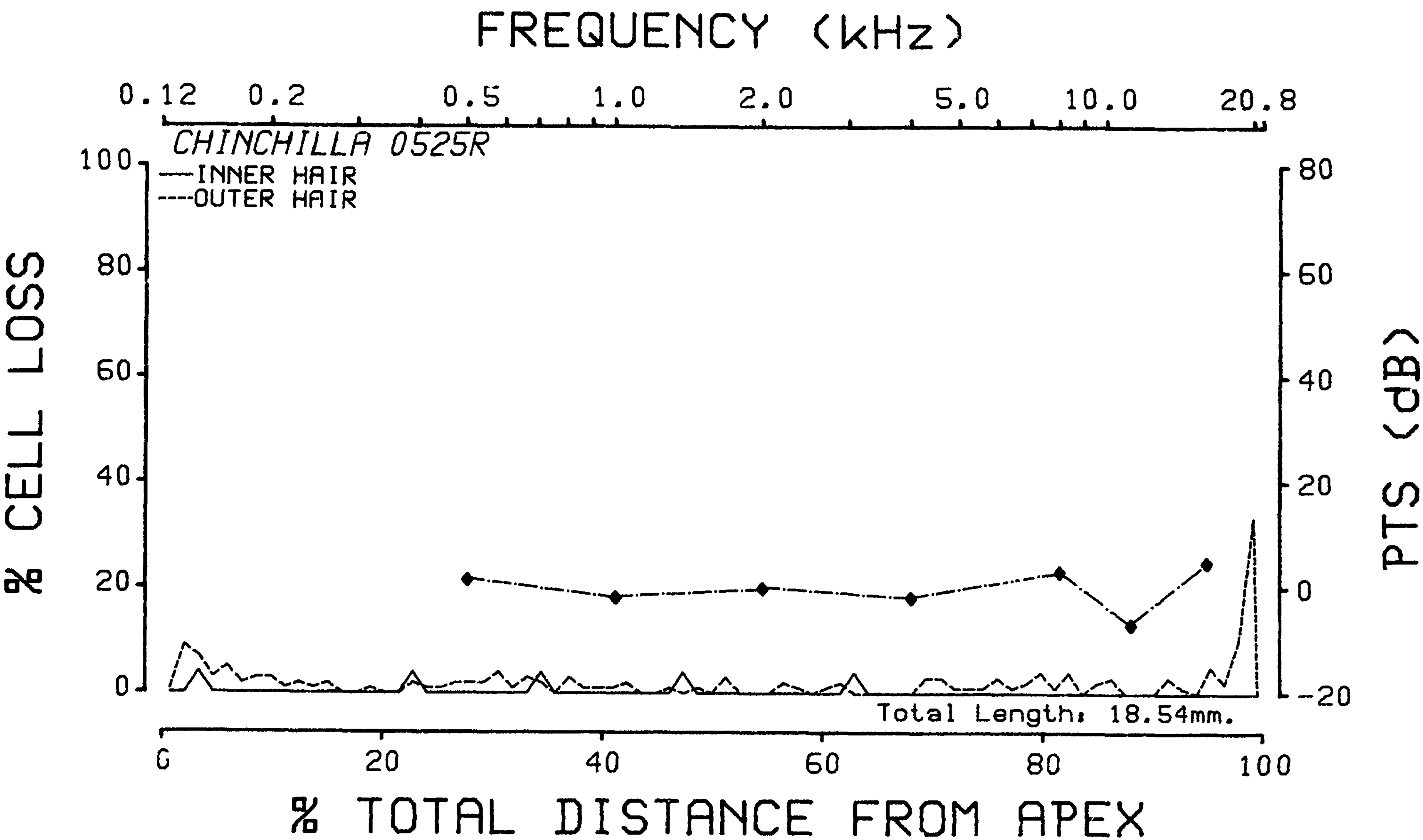
150 dB 100X 10/M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

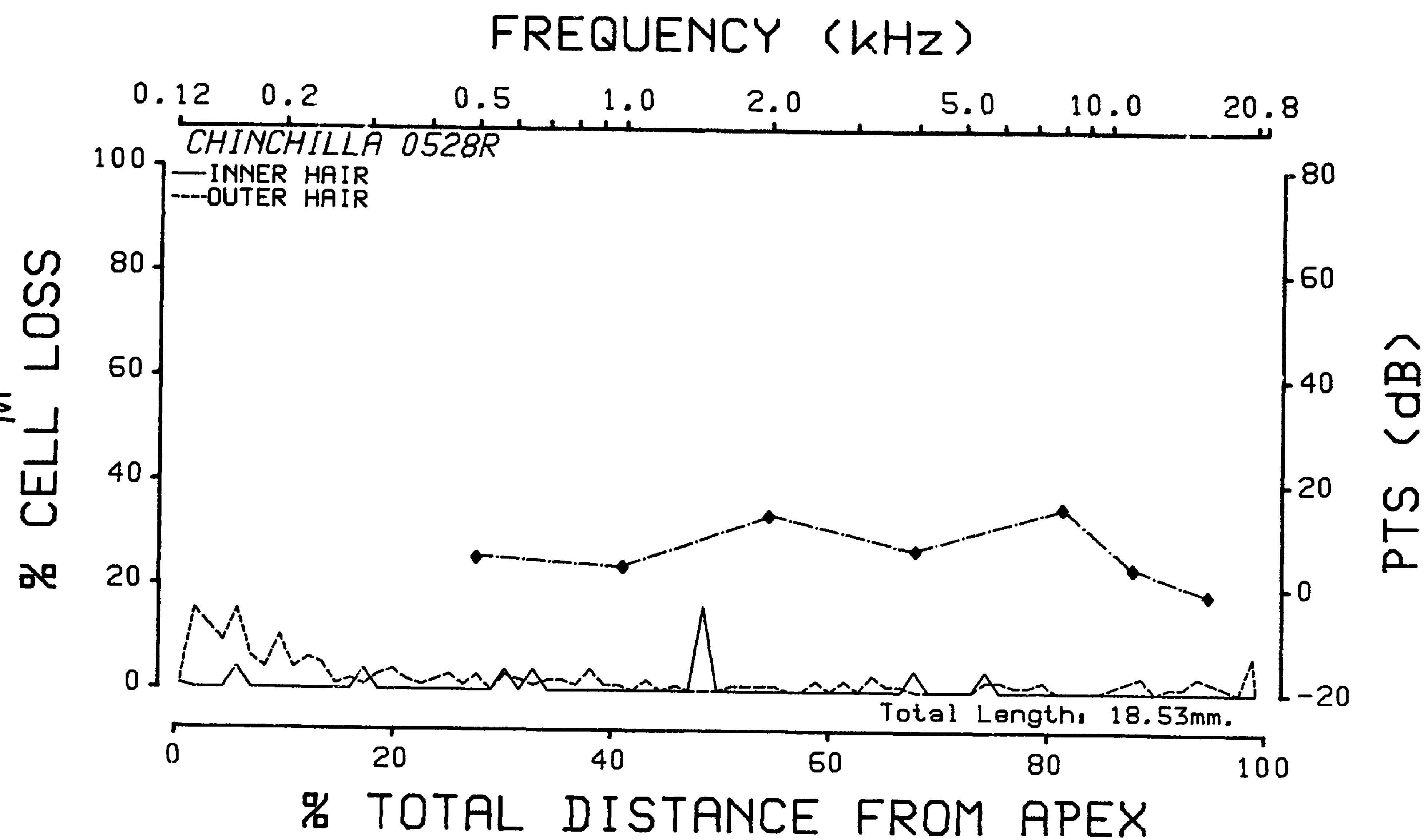
	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0536							
0.125 kHz	1	0	4	21	25	0	2
0.25 kHz	2	1	1	12	14	0	0
0.5 kHz	1	2	3	3	8	2	0
1 kHz	4	2	0	3	5	0	0
2 kHz	1	3	0	4	7	0	0
4 kHz	1	0	0	0	0	0	0
8 kHz	1	0	0	1	1	0	0
16 kHz	0	0	0	1	1	0	0
TOTALS	11	8	8	45	61	2	2
CHINCHILLA 0538							
0.125 kHz	1	14	10	12	36	0	0
0.25 kHz	1	26	6	27	59	0	0
0.5 kHz	0	11	21	20	52	1	0
1 kHz	0	13	8	4	25	3	0
2 kHz	0	3	0	6	9	0	0
4 kHz	0	6	1	7	14	0	0
8 kHz	0	1	0	15	16	0	0
16 kHz	0	1	2	20	23	0	0
TOTALS	2	75	48	111	234	4	0
GROUP MEANS							
0.125 kHz	1.8	7.2	12.2	24.4	43.8	0.0	1.0
0.25 kHz	1.2	9.4	3.8	26.2	39.4	0.0	0.8
0.5 kHz	1.0	4.2	8.8	12.8	25.8	0.8	0.0
1 kHz	1.4	4.6	4.0	4.6	13.2	0.8	0.0
2 kHz	1.0	3.0	1.0	2.6	6.6	0.0	0.0
4 kHz	1.4	3.2	2.6	2.8	8.6	0.0	0.2
8 kHz	0.4	1.8	2.4	7.0	11.2	0.2	0.0
16 kHz	0.2	8.0	5.0	9.6	22.6	0.0	0.4
TOTALS	8.4	41.4	39.8	90.0	171.2	1.8	2.4

Cochleograms and PTS Audiograms

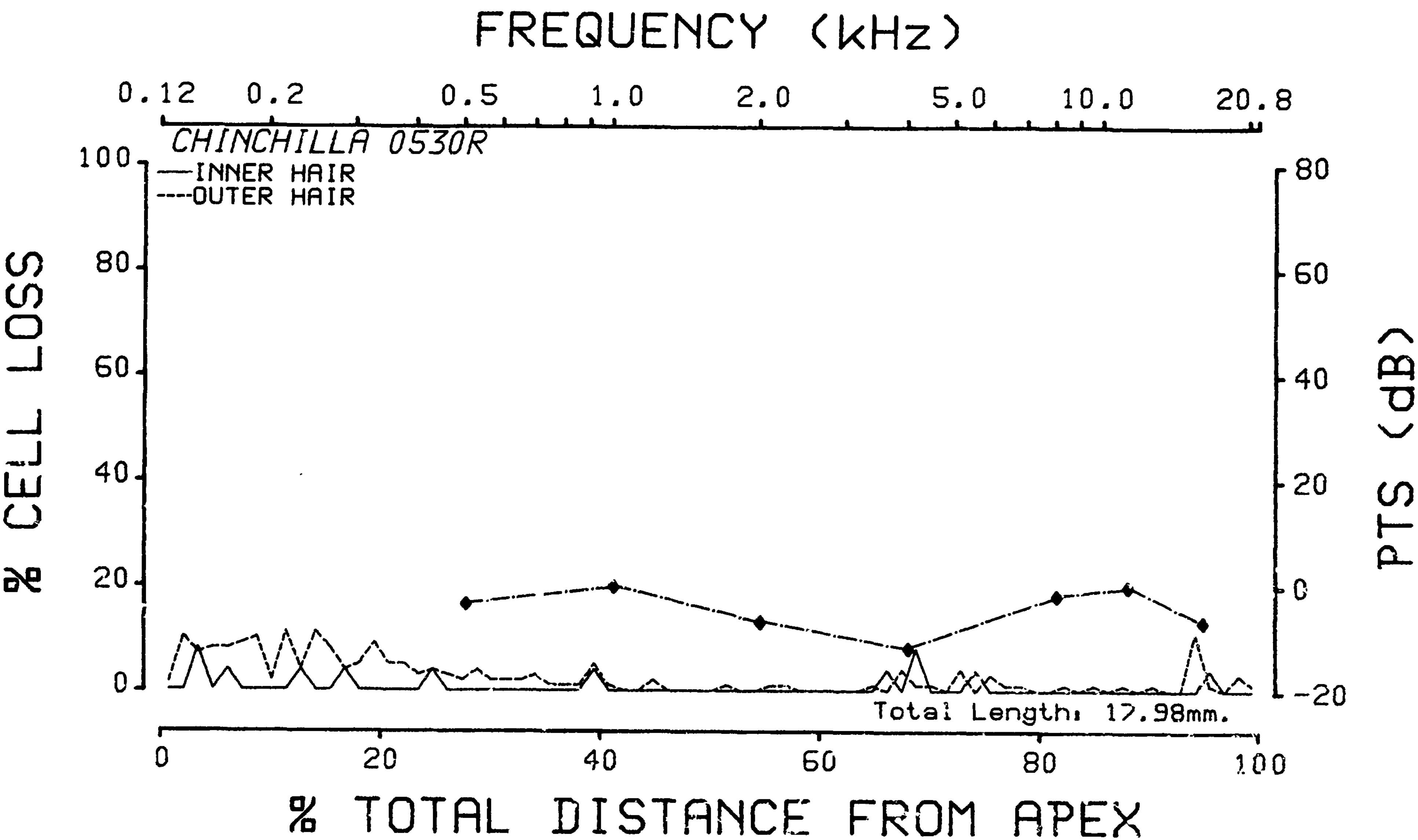
for Individual Animals

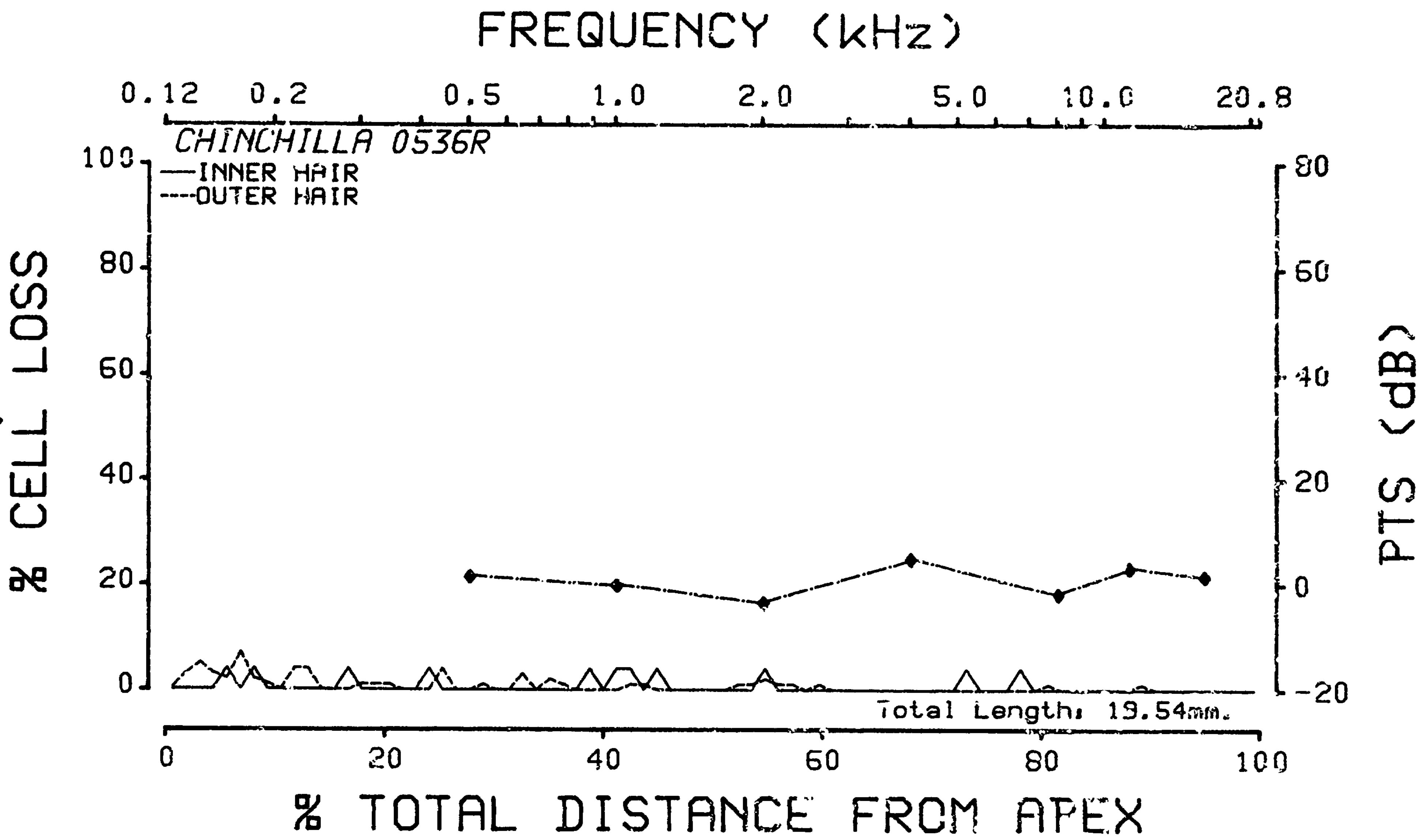


FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
CHINCHILLA 0525R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100 80 60 40 20 0
PTS (dB)
80 60 40 20 0 -20
Total Length: 18.54mm.
0 20 40 60 80 100
% TOTAL DISTANCE FROM APEX

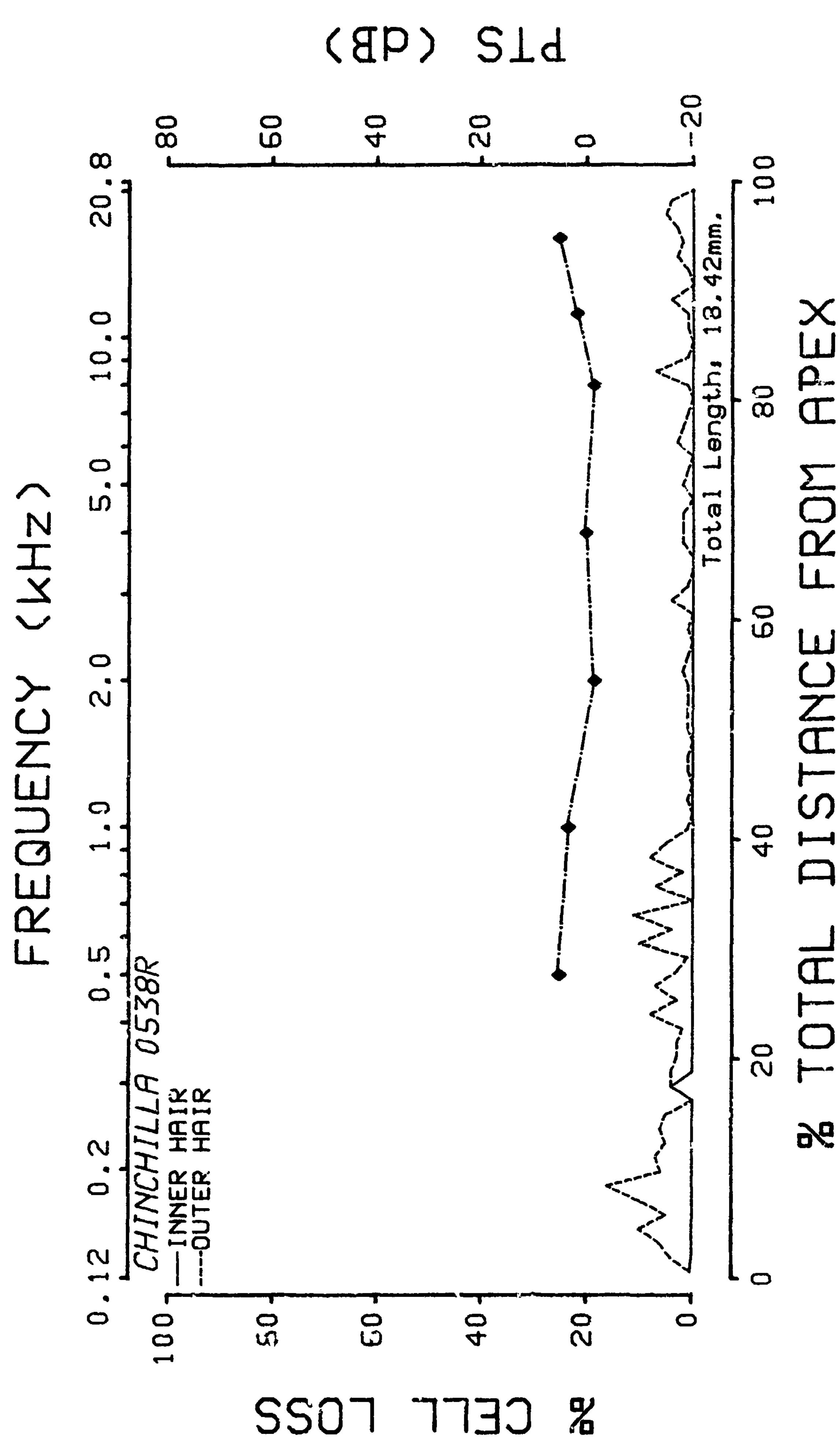


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0528R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.53mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0530R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.98mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
CHINCHILLA 0536R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100 80 60 40 20 0
PTS (dB)
80 60 40 20 0 −20
Total Length: 19.54mm.
0 20 40 60 80 100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
80
60
40
20
0
-20
% CELL LOSS
100
80
60
40
20
0
CHINCHILLA 0538R
—INNER HAIR
---OUTER HAIR
Total Length: 18.42mm.
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100

Summary Data for the Group Exposed to:

150 dB, 100X, 1/10M

Animal #

0553	-	Completed the Entire Protocol
0556	-	Completed the Entire Protocol
0557	-	Completed the Entire Protocol
0558	-	Completed the Entire Protocol
0559	-	Completed the Entire Protocol

150 dB 100X 1/10M

PRE-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0553	24.2	4.2	2.5	2.5	17.5	4.2	10.8
0556	22.5	5.8	10.8	9.2	19.2	15.8	27.5
0557	20.8	4.2	2.5	-0.8	14.2	9.2	24.2
0558	17.5	4.2	4.2	-0.8	12.5	10.8	12.5
0559	19.2	9.2	2.5	2.5	10.8	14.2	12.5
Mean	20.8	5.5	4.5	2.5	14.8	10.8	17.5
S.D.	2.6	2.2	3.6	4.1	3.5	4.6	7.7

POST-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0553	22.5	4.2	2.5	4.2	15.8	4.2	14.2
0556	20.8	7.5	14.2	7.5	24.2	15.8	27.5
0557	17.5	-2.5	-0.8	-0.8	12.5	9.2	27.5
0558	19.2	4.2	4.2	4.2	12.5	10.8	5.8
0559	22.5	7.5	10.8	7.5	14.2	22.5	20.8
Mean	20.5	4.2	6.2	4.5	15.8	12.5	19.2
S.D.	2.2	4.1	6.2	3.4	4.9	7.0	9.3

PERMANENT THRESHOLD SHIFT (dB)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0553	-1.7	0.0	0.0	1.7	-1.7	0.0	3.3
0556	-1.7	1.7	3.3	-1.7	5.0	0.0	0.0
0557	-3.3	-6.7	-3.3	0.0	-1.7	0.0	3.3
0558	1.7	0.0	0.0	5.0	0.0	0.0	-6.7
0559	3.3	-1.7	8.3	5.0	3.3	8.3	8.3
Mean	-0.3	-1.3	1.7	2.0	1.0	1.7	1.7
S.D.	2.7	3.2	4.4	3.0	3.0	3.7	5.5

150 dB 100X 1/10M

TEMPORARY THRESHOLD SHIFT (dB)

Frequency 0.5 kHz

Animal\Hr	0	2	8	24	240	Max
0553	18.3	3.3	-1.7	3.3	13.3	18.3
0556	20.0	0.0	0.0	5.0	-5.0	20.0
0557	-3.3	-8.3	-3.3	-8.3	-8.3	-3.3
0558	0.0	0.0	0.0	0.0	5.0	5.0
0559	3.3	8.3	3.3	3.3	-1.7	8.3
Mean	7.7	0.7	-0.3	0.7	0.7	9.7
S.D.	10.8	6.1	2.5	5.3	8.6	9.7

Frequency 2.0 kHz

Animal\Hr	0	2	8	24	240	Max
0553	20.0	15.0	5.0	10.0	5.0	20.0
0556	11.7	1.7	6.7	6.7	-3.3	11.7
0557	5.0	-5.0	0.0	-5.0	-5.0	5.0
0558	8.3	8.3	3.3	3.3	-1.7	8.3
0559	15.0	10.0	10.0	15.0	5.0	15.0
Mean	12.0	6.0	5.0	6.0	0.0	12.0
S.D.	5.8	7.8	3.7	7.5	4.7	5.8

Frequency 8.0 kHz

Animal\Hr	0	2	8	24	240	Max
0553	5.0	-5.0	5.0	5.0	5.0	5.0
0556	3.3	3.3	-1.7	-1.7	-1.7	3.3
0557	-1.7	-6.7	-1.7	-6.7	3.3	3.3
0558	0.0	5.0	0.0	0.0	0.0	5.0
0559	21.7	11.7	11.7	11.7	11.7	21.7
Mean	5.7	1.7	2.7	1.7	3.7	7.7
S.D.	9.3	7.6	5.7	7.0	5.2	7.9

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 1/10M

Probe Frequency: 0.5 kHz

Masker (kHz):		0.150	0.200	0.300	0.400	0.520	0.600	0.650	0.750	1.300	2.200
Animal	(Q-10 dB)	Pre-Exposure									
0553	(2.09)	67.5	67.5	57.5	42.5	32.5	37.5	42.5	57.5	82.5	95.0*
0556	(2.84)	72.5	67.5	57.5	57.5	47.5	42.5	37.5	47.5	82.5	87.5
0557	(2.41)	72.5	67.5	62.5	52.5	47.5	42.5	52.5	57.5	77.5	95.0*
0558	(1.87)	82.5	67.5	52.5	42.5	37.5	42.5	52.5	52.5	77.5	95.0*
0559	(3.64)	72.5	67.5	62.5	47.5	27.5	37.5	42.5	47.5	77.5	95.0*
Mean	(2.57)	73.5	67.5	58.5	48.5	38.5	40.5	45.5	52.5	79.5	93.5
S.D.	(0.70)	5.5	0.0	4.2	6.5	8.9	2.7	6.7	5.0	2.7	3.4
Animal	(Q-10 dB)	Post-Exposure									
0553	(1.41)	62.5	57.5	52.5	42.5	37.5	42.5	37.5	52.5	57.5	95.0*
0556	(1.72)	67.5	62.5	52.5	47.5	42.5	37.5	37.5	47.5	72.5	95.0*
0557	(1.66)	72.5	67.5	62.5	52.5	37.5	42.5	42.5	47.5	82.5	95.0*
0558	(1.49)	67.5	67.5	47.5	42.5	32.5	37.5	37.5	42.5	72.5	95.0*
0559	(1.72)	67.5	62.5	57.5	52.5	47.5	42.5	47.5	52.5	92.5	95.0*
Mean	(1.60)	67.5	63.5	54.5	47.5	39.5	40.5	40.5	48.5	75.5	95.0
S.D.	(0.14)	3.5	4.2	5.7	5.0	5.7	2.7	4.5	4.2	13.0	0.0

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 1/10M

Probe Frequency: 1.0 kHz

Masker (kHz):		0.150	0.200	0.400	0.550	0.800	1.050	1.300	1.700	1.900	2.500
Animal	(Q-10 dB)					Pre-Exposure					
0553	(1.78)	67.5	62.5	57.5	52.5	32.5	22.5	27.5	47.5	62.5	77.5
0556	(2.55)	82.5	72.5	62.5	52.5	22.5	12.5	27.5	47.5	57.5	87.5
0557	(2.73)	82.5	77.5	67.5	57.5	47.5	27.5	37.5	77.5	77.5	91.0*
0558	(2.10)	77.5	72.5	57.5	47.5	32.5	22.5	32.5	47.5	57.5	87.5
0559	(2.55)	77.5	72.5	57.5	52.5	32.5	22.5	37.5	57.5	62.5	87.5
Mean	(2.34)	77.5	71.5	60.5	52.5	33.5	21.5	32.5	55.5	63.5	86.2
S.D.	(0.40)	6.1	5.5	4.5	3.5	8.9	5.5	5.0	13.0	8.2	5.1
Animal	(Q-10 dB)					Post-Exposure					
0553	(2.73)	67.5	62.5	57.5	52.5	37.5	17.5	27.5	52.5	62.5	77.5
0556	(2.92)	72.5	67.5	57.5	47.5	47.5	22.5	32.5	62.5	62.5	87.5
0557	(3.57)	72.5	72.5	62.5	57.5	37.5	17.5	32.5	62.5	77.5	91.0*
0558	(2.55)	82.5	72.5	57.5	52.5	32.5	22.5	37.5	47.5	57.5	91.0*
0559	(2.85)	77.5	67.5	62.5	47.5	27.5	17.5	37.5	47.5	52.5	77.5
Mean	(2.93)	74.5	68.5	59.5	51.5	36.5	19.5	33.5	54.5	62.5	84.9
S.D.	(0.39)	5.7	4.2	2.7	4.2	7.4	2.7	4.2	7.6	9.4	6.9

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 1/10M

Probe Frequency: 2.0 kHz

Masker (kHz):		0.300	0.750	0.900	1.300	1.700	2.050	2.200	3.000	3.500	4.000
Animal	(Q-10 dB)					Pre-Exposure					
0553	(3.58)	72.5	67.5	57.5	37.5	37.5	17.5	22.5	37.5	52.5	77.5
0556	(4.09)	72.5	57.5	52.5	37.5	37.5	27.5	37.5	47.5	57.5	62.5
0557	(4.04)	87.5	57.5	47.5	47.5	42.5	27.5	32.5	62.5	77.5	96.0*
0558	(1.72)	72.5	52.5	37.5	32.5	27.5	22.5	22.5	47.5	77.5	96.0*
0559	(5.24)	67.5	47.5	37.5	32.5	27.5	12.5	22.5	52.5	57.5	57.5
Mean	(3.74)	74.5	56.5	46.5	37.5	34.5	21.5	27.5	49.5	64.5	77.9
S.D.	(1.28)	7.6	7.4	8.9	6.1	6.7	6.5	7.1	9.1	12.0	18.1
Animal	(Q-10 dB)					Post-Exposure					
0553	(4.32)	77.5	67.5	62.5	52.5	37.5	17.5	22.5	47.5	57.5	67.5
0556	(1.62)	87.5	57.5	47.5	42.5	37.5	32.5	37.5	47.5	57.5	96.0*
0557	(3.32)	87.5	57.5	47.5	37.5	32.5	22.5	27.5	57.5	72.5	96.0*
0558	(3.20)	72.5	52.5	37.5	37.5	27.5	17.5	22.5	47.5	82.5	96.0*
0559	(0.88)	72.5	52.5	37.5	27.5	32.5	32.5	32.5	52.5	67.5	82.5
Mean	(2.67)	79.5	57.5	46.5	39.5	33.5	24.5	28.5	50.5	67.5	87.6
S.D.	(1.39)	7.6	6.1	10.2	9.1	4.2	7.6	6.5	4.5	10.6	12.7

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 1/10M

Probe Frequency: 4.0 kHz

Masker (kHz):		0.450	1.300	2.200	3.000	3.500	4.100	4.500	5.000	5.600	6.000
Animal	(Q-10 dB)	Pre-Exposure									
0553	(2.63)	72.5	57.5	52.5	52.5	27.5	27.5	32.5	52.5	77.5	82.5
0556	(5.77)	77.5	52.5	52.5	52.5	47.5	27.5	37.5	47.5	57.5	67.5
0557	(3.53)	82.5	52.5	47.5	52.5	32.5	22.5	27.5	42.5	72.5	87.5
0558	(3.04)	77.5	47.5	47.5	47.5	22.5	17.5	22.5	32.5	42.5	57.5
0559	(3.13)	72.5	52.5	47.5	52.5	32.5	17.5	22.5	27.5	47.5	67.5
Mean	(3.62)	76.5	52.5	49.5	51.5	32.5	22.5	28.5	40.5	59.5	72.5
S.D.	(1.24)	4.2	3.5	2.7	2.2	9.4	5.0	6.5	10.4	15.2	12.2
Animal	(Q-10 dB)	Post-Exposure									
0553	(2.68)	82.5	57.5	52.5	52.5	27.5	32.5	32.5	57.5	67.5	92.5
0556	(4.23)	72.5	52.5	52.5	47.5	22.5	17.5	32.5	42.5	47.5	62.5
0557	(3.24)	72.5	52.5	47.5	52.5	27.5	22.5	27.5	42.5	42.5	67.5
0558	(2.78)	72.5	52.5	47.5	42.5	22.5	22.5	32.5	37.5	52.5	82.5
0559	(4.41)	77.5	47.5	52.5	62.5	22.5	17.5	32.5	37.5	67.5	77.5
Mean	(3.47)	75.5	52.5	50.5	51.5	24.5	22.5	31.5	43.5	55.5	76.5
S.D.	(0.81)	4.5	3.5	2.7	7.4	2.7	6.1	2.2	8.2	11.5	11.9

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 1/10M

Probe Frequency: 8.0 kHz

Masker (kHz):		0.450	1.300	2.500	5.900	7.000	8.100	9.300	11.000	12.700	14.000
Animal	(Q-10 dB)					Pre-Exposure					
0553	(3.09)	97.5	77.5	67.5	57.5	57.5	47.5	52.5	77.5	97.5	95.0*
0556	(3.18)	82.5	67.5	62.5	42.5	32.5	42.5	52.5	62.5	82.5	92.5
0557	(8.89)	87.5	57.5	57.5	47.5	57.5	22.5	42.5	72.5	92.5	95.0*
0558	(5.29)	82.5	57.5	57.5	42.5	42.5	27.5	42.5	67.5	97.5	95.0*
0559	(4.58)	77.5	57.5	57.5	37.5	37.5	17.5	27.5	52.5	62.5	77.5
Mean	(5.01)	85.5	63.5	60.5	45.5	45.5	31.5	43.5	66.5	86.5	91.0
S.D.	(2.36)	7.6	8.9	4.5	7.6	11.5	12.9	10.2	9.6	14.7	7.6
Animal	(Q-10 dB)					Post-Exposure					
0553	(2.06)	82.5	57.5	67.5	47.5	42.5	37.5	37.5	67.5	100.0*	95.0*
0556	(1.36)	82.5	77.5	62.5	47.5	47.5	42.5	42.5	57.5	77.5	77.5
0557	(7.28)	72.5	57.5	52.5	47.5	57.5	22.5	37.5	67.5	87.5	87.5
0558	(4.31)	82.5	57.5	52.5	37.5	27.5	17.5	32.5	47.5	52.5	77.5
0559	(3.00)	57.5	47.5	42.5	47.5	37.5	27.5	32.5	52.5	57.5	72.5
Mean	(3.60)	75.5	59.5	55.5	45.5	42.5	29.5	36.5	58.5	75.0	82.0
S.D.	(2.33)	11.0	11.0	9.7	4.5	11.2	10.4	4.2	8.9	20.0	9.1

MASKED THRESHOLDS (dB SPL) Group: 150 dB 100X 1/10M

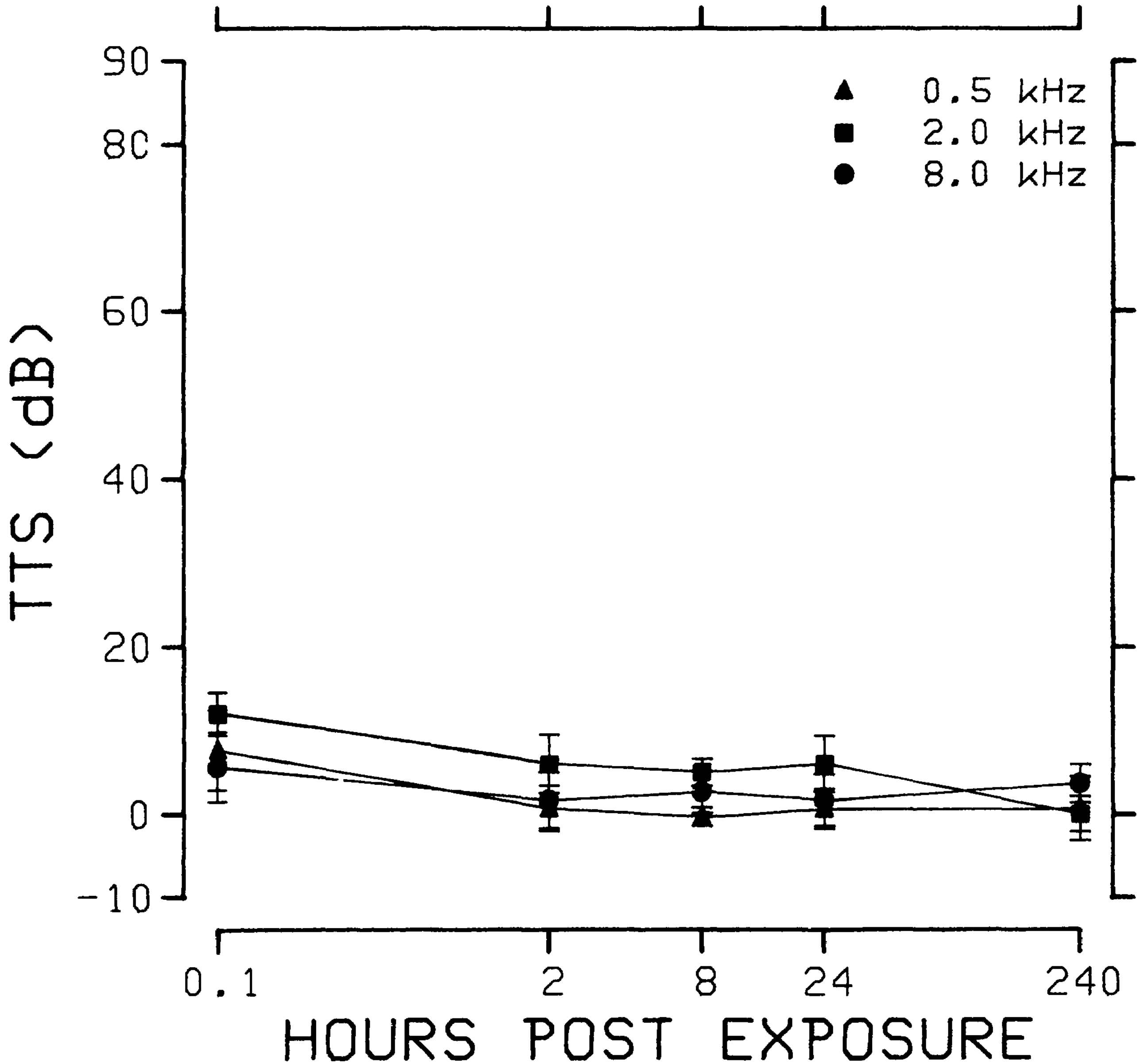
Probe Frequency: 11.2 kHz

Masker (kHz):		1.000	4.000	7.000	9.000	11.000	11.500	12.000	13.000	14.500	16.000
Animal (Q-10 dB)						Pre-Exposure					
0553	(3.49)	72.5	62.5	62.5	47.5	32.5	32.5	27.5	27.5	47.5	62.5
0556	(8.15)	67.5	62.5	57.5	52.5	27.5	37.5	32.5	32.5	47.5	72.5
0557	(3.77)	67.5	57.5	62.5	57.5	47.5	42.5	47.5	52.5	67.5	87.5
0558	(3.61)	62.5	57.5	57.5	47.5	27.5	32.5	32.5	37.5	62.5	72.5
0559	(6.89)	67.5	52.5	57.5	52.5	27.5	32.5	42.5	52.5	52.5	77.5
Mean	(5.18)	67.5	58.5	59.5	51.5	32.5	35.5	36.5	40.5	55.5	74.5
S.D.	(2.19)	3.5	4.2	2.7	4.2	8.7	4.5	8.2	11.5	9.1	9.1
Animal (Q-10 dB)						Post-Exposure					
0553	(6.24)	62.5	57.5	47.5	47.5	37.5	32.5	27.5	22.5	47.5	62.5
0556	(3.26)	62.5	62.5	57.5	47.5	32.5	32.5	37.5	42.5	57.5	67.5
0557	(3.37)	67.5	57.5	72.5	62.5	37.5	37.5	37.5	37.5	72.5	82.5
0558	(10.59)	62.5	62.5	57.5	57.5	17.5	27.5	27.5	32.5	57.5	77.5
0559	(3.86)	67.5	57.5	62.5	57.5	32.5	37.5	37.5	42.5	62.5	77.5
Mean	(5.47)	64.5	59.5	59.5	54.5	31.5	33.5	33.5	35.5	59.5	73.5
S.D.	(3.11)	2.7	2.7	9.1	6.7	8.2	4.2	5.5	8.4	9.1	8.2

The Group Mean Recovery Curves

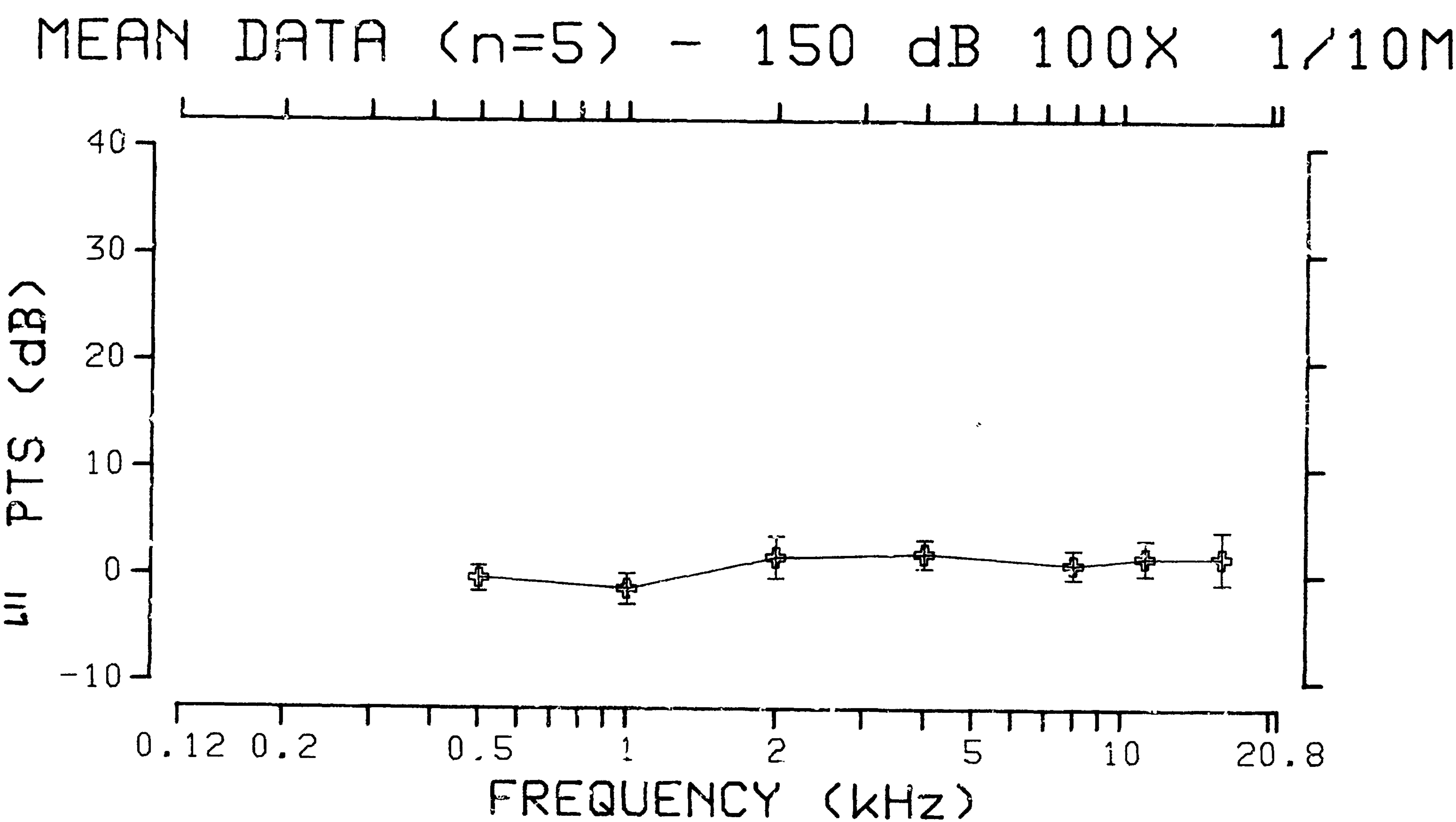
Measured at Three Test Frequencies

MEAN DATA (n=5) - 150 dB 100X 1/10M



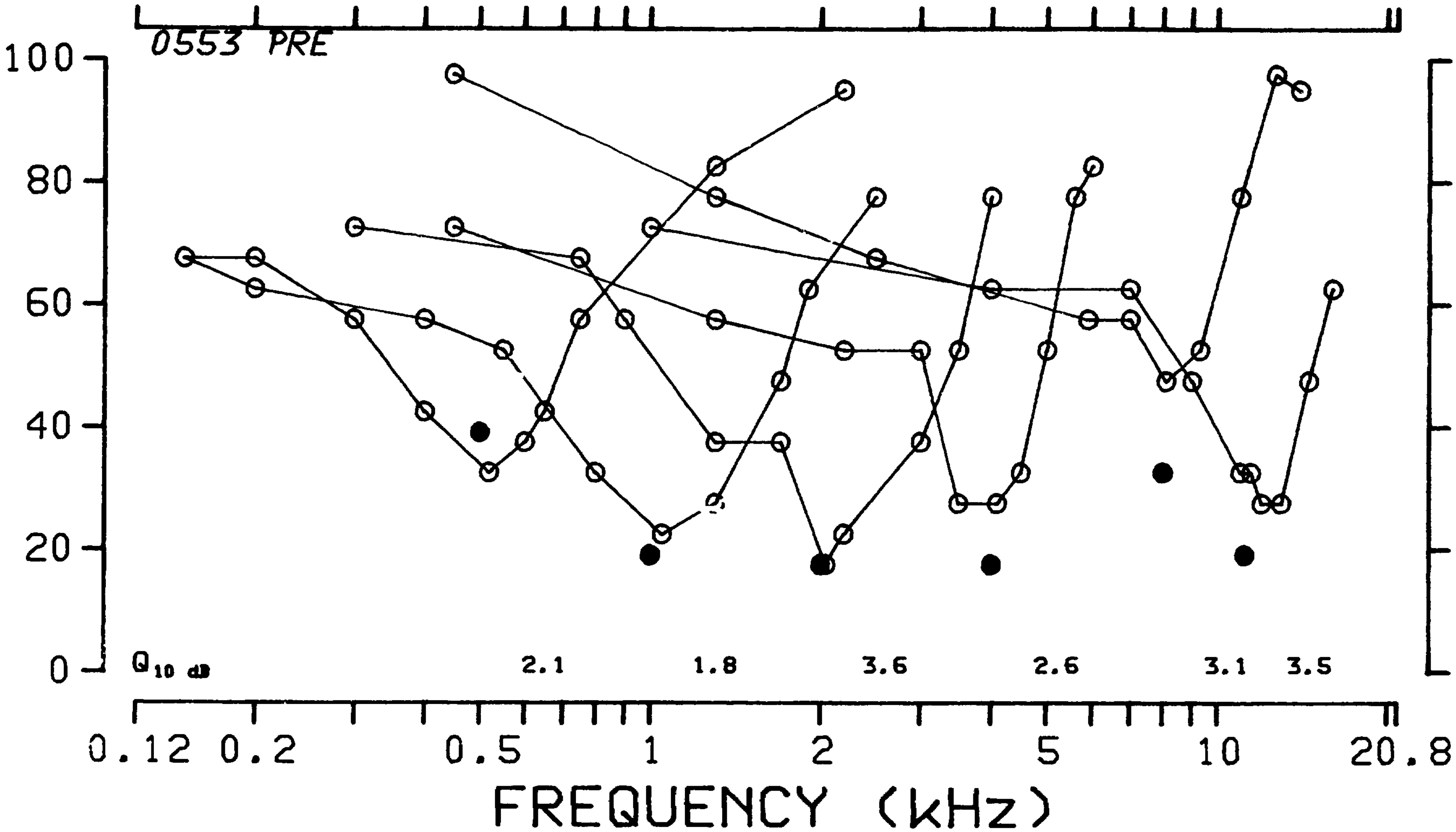
The Group Mean Permanent Threshold Shift (PTS)

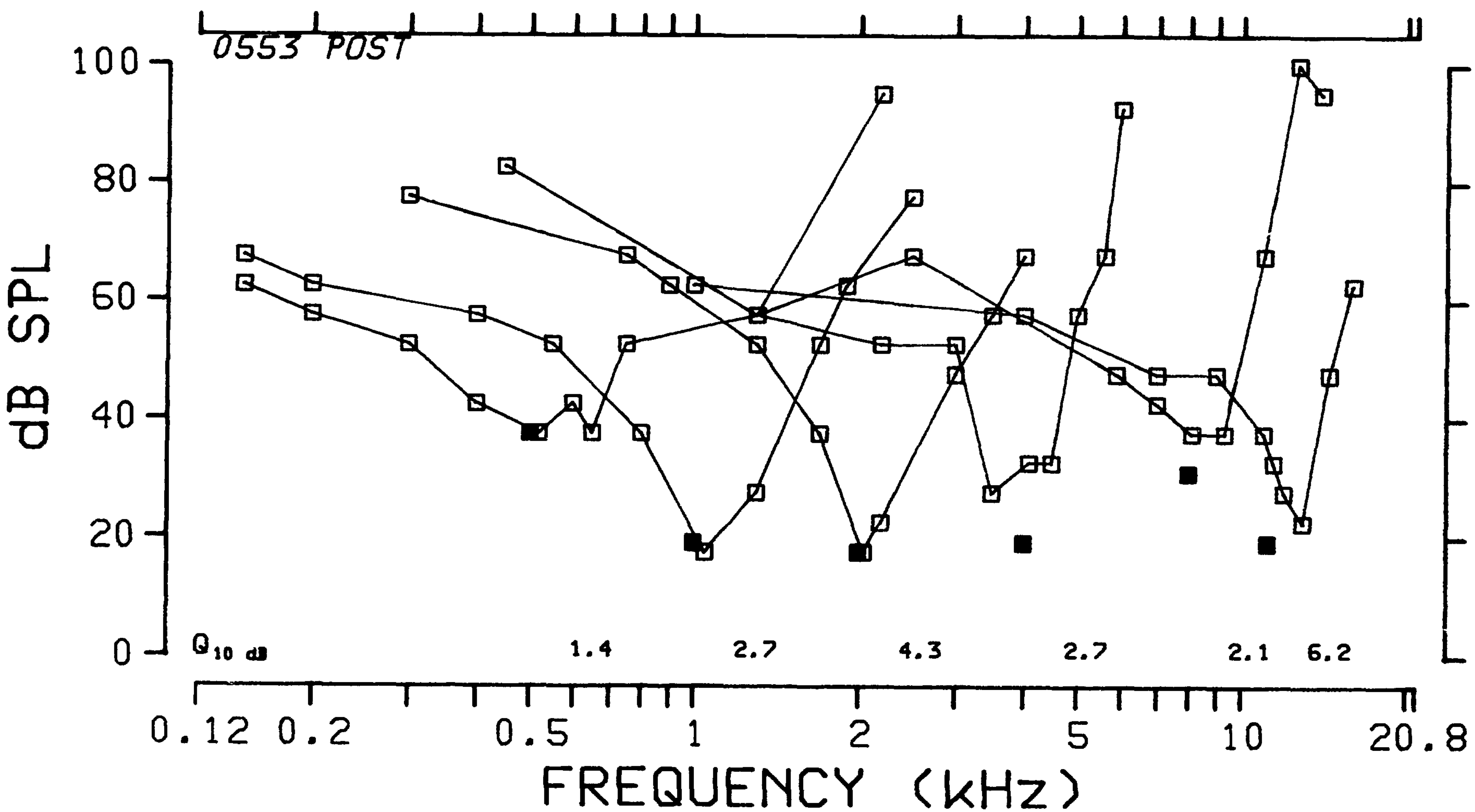
for all Test Frequencies

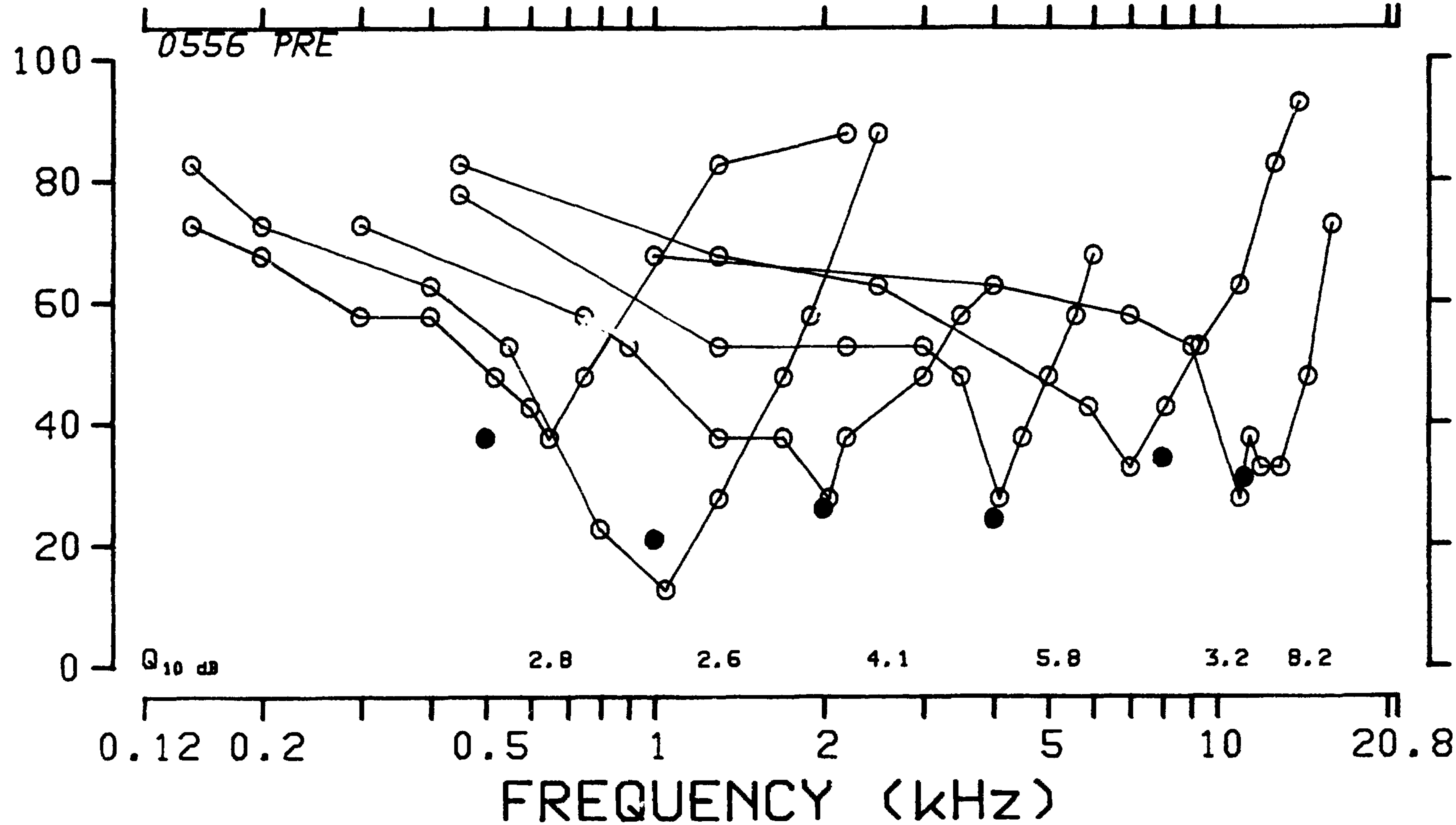

MEAN DATA (n=5) - 150 dB 100X 1/10M
40
30
20
10
0
-10
PTS (dB)
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

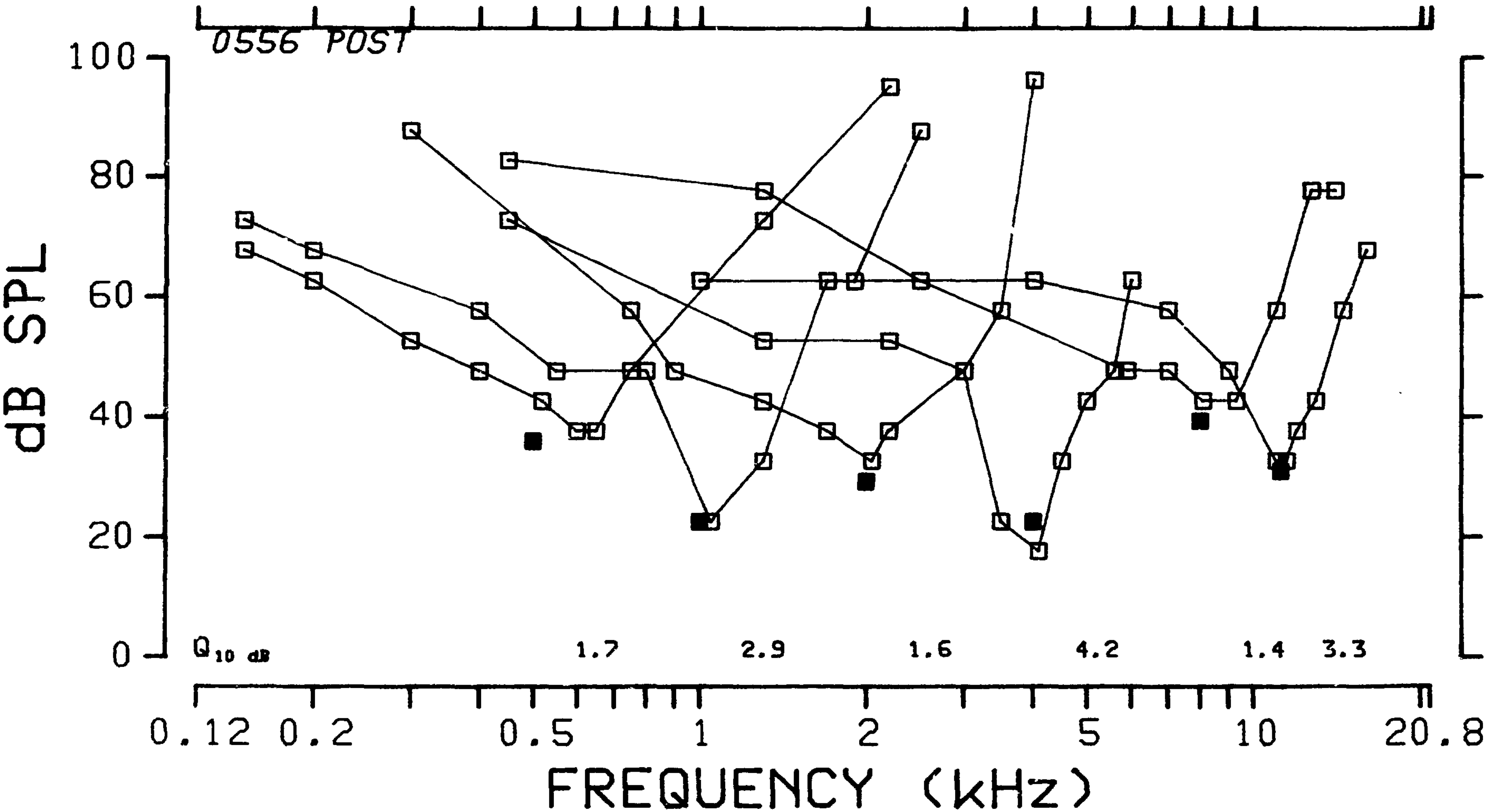
The Pre and Postexposure Tuning Curves for
Individual Animals in this Exposure Group.

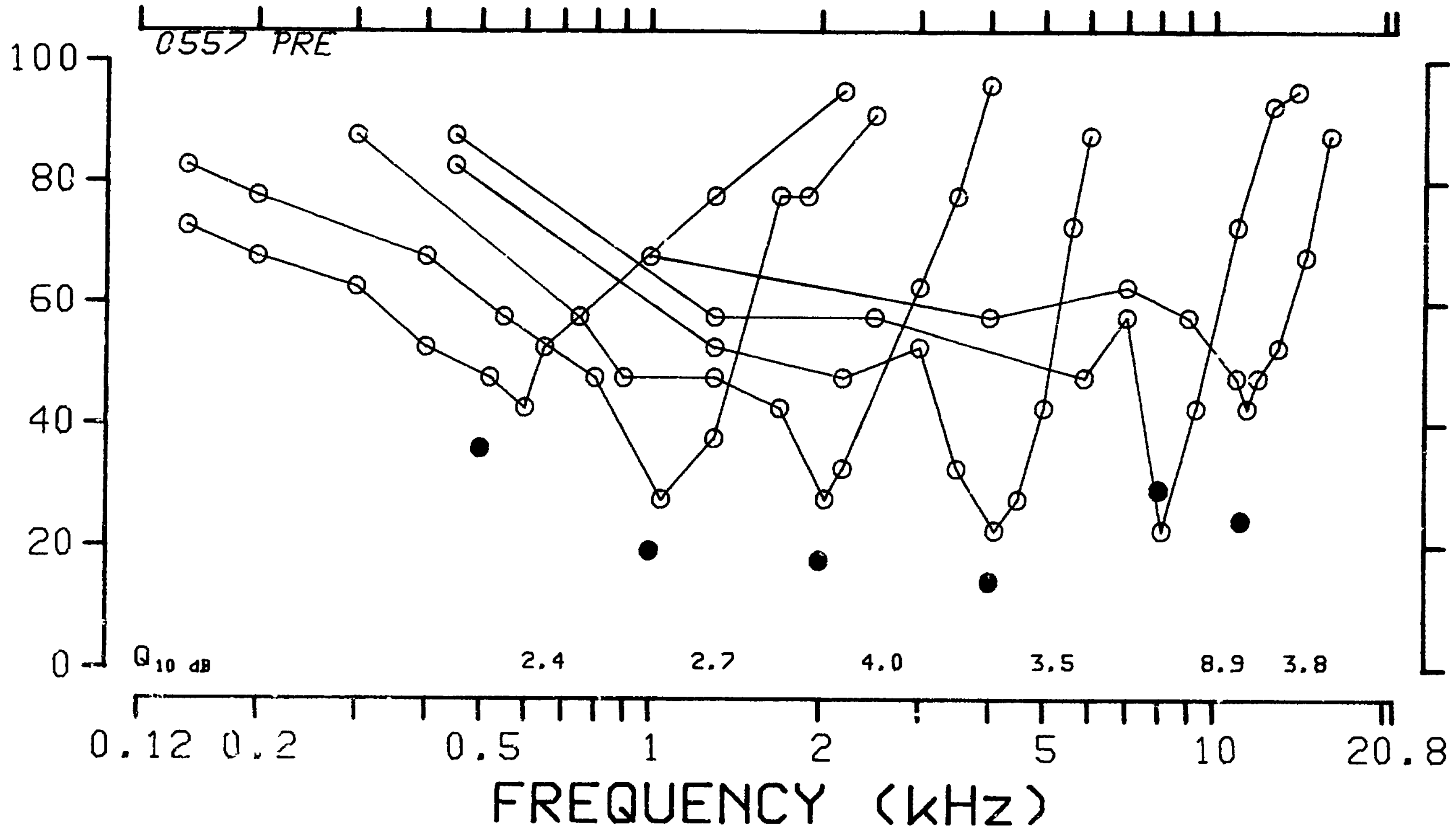
The Solid Symbol represents the intensity of the probe tone.

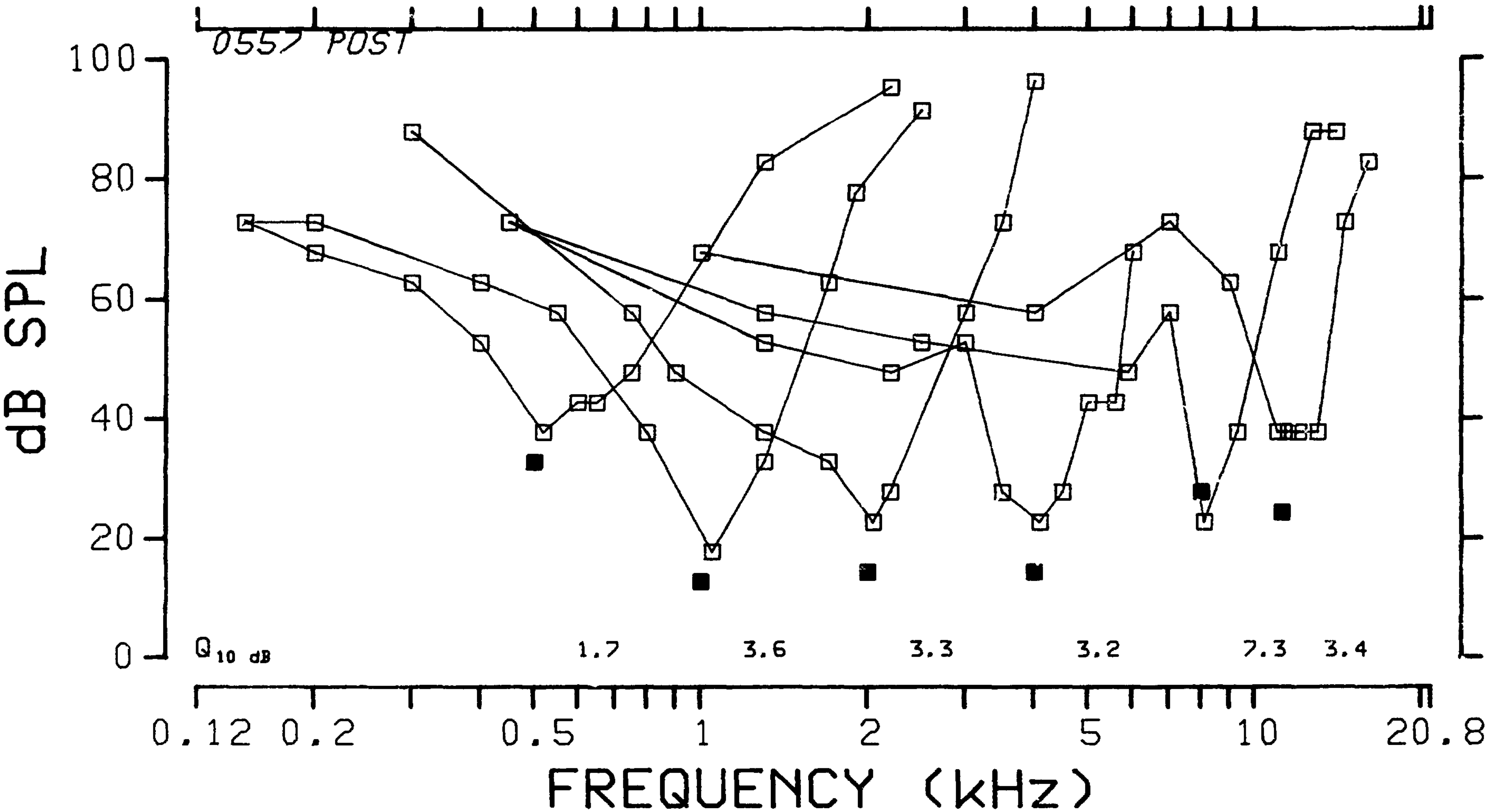

0553 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
2.1
1.8
3.6
2.6
3.1
3.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

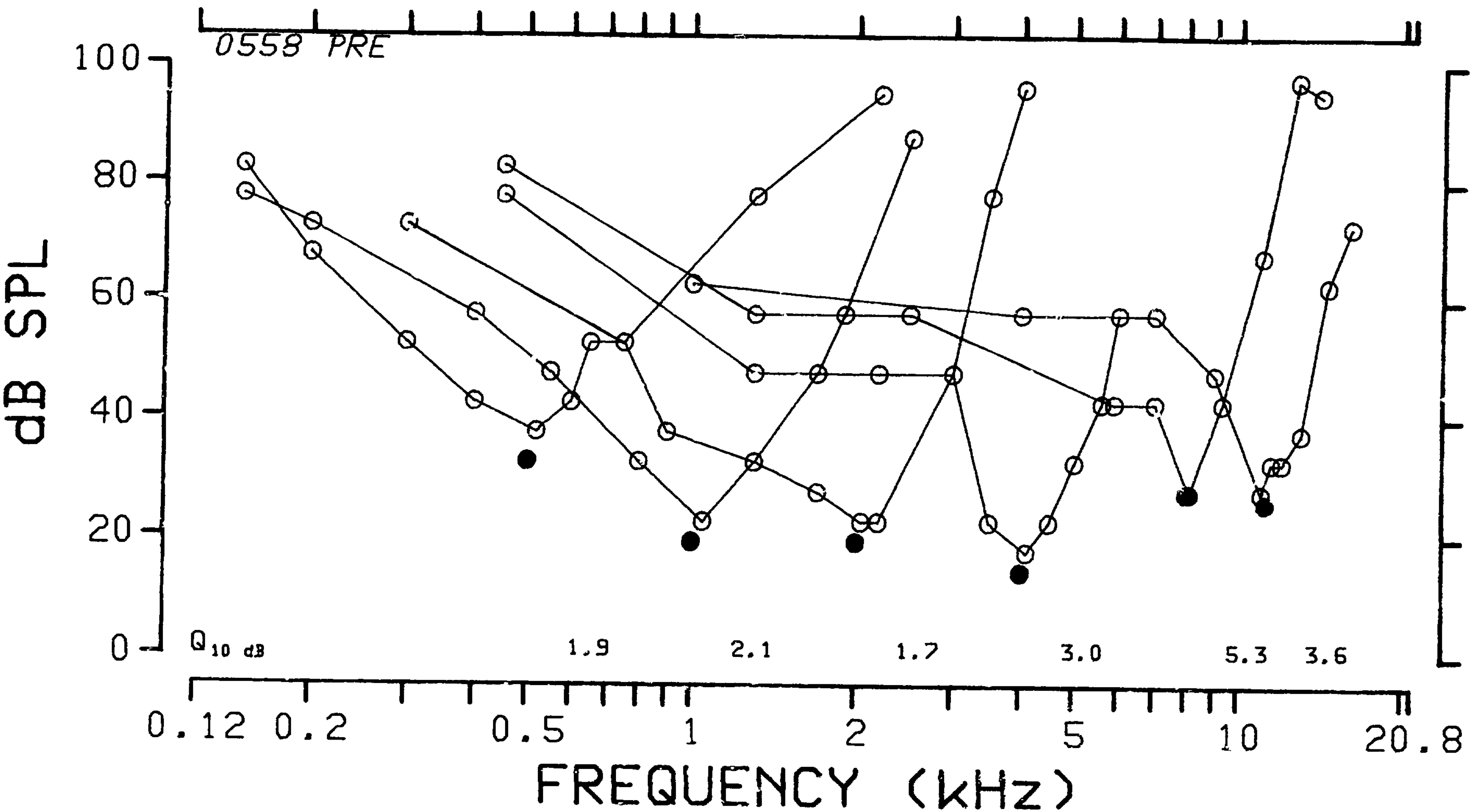

0553 POST
100
80
60
40
20
0
dB SPL
Q10 dB
1.4
2.7
4.3
2.7
2.1
6.2
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0556 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
2.8
2.6
4.1
5.8
3.2
8.2
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

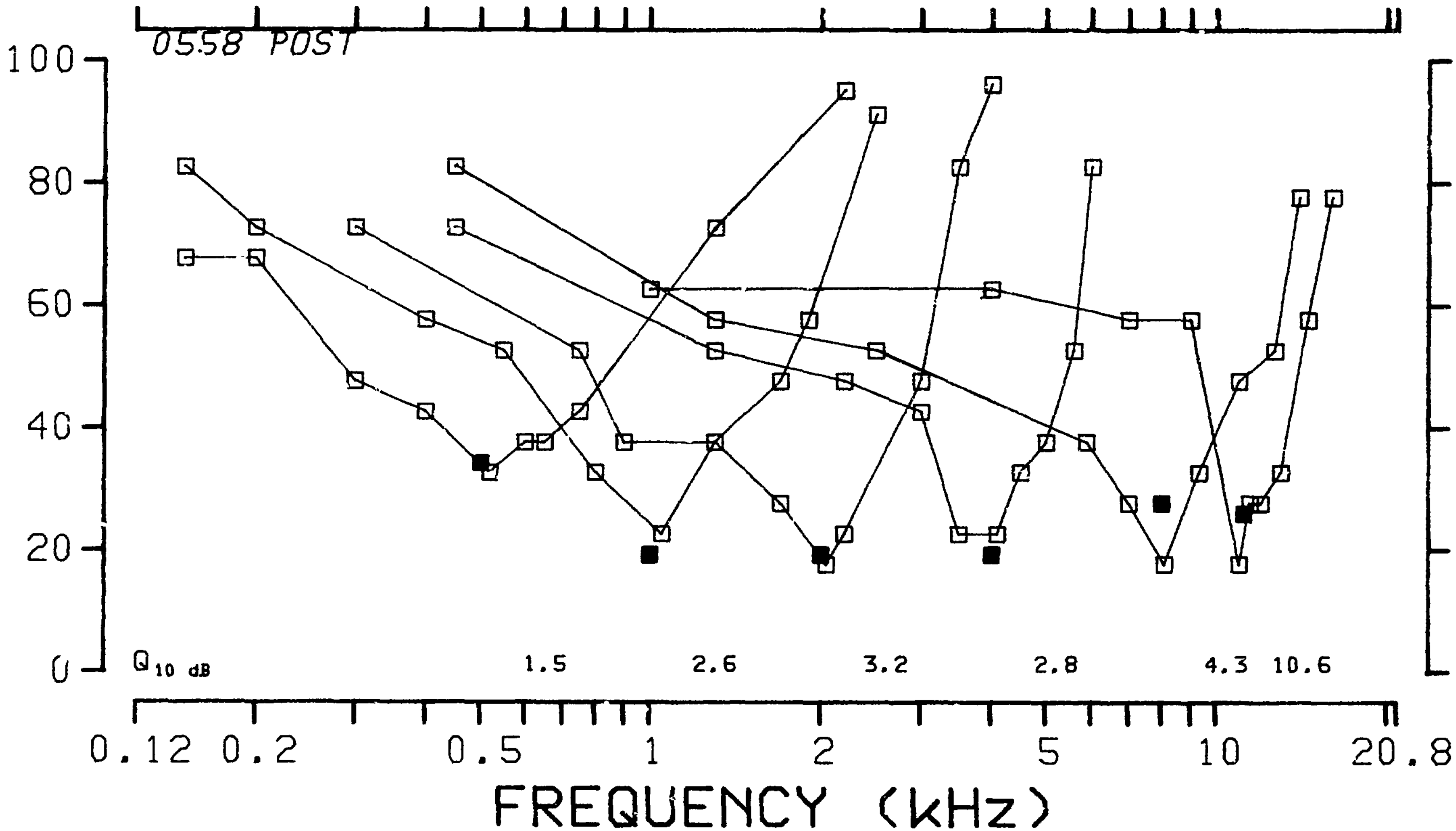

0556 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.7
2.9
1.6
4.2
1.4
3.3
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

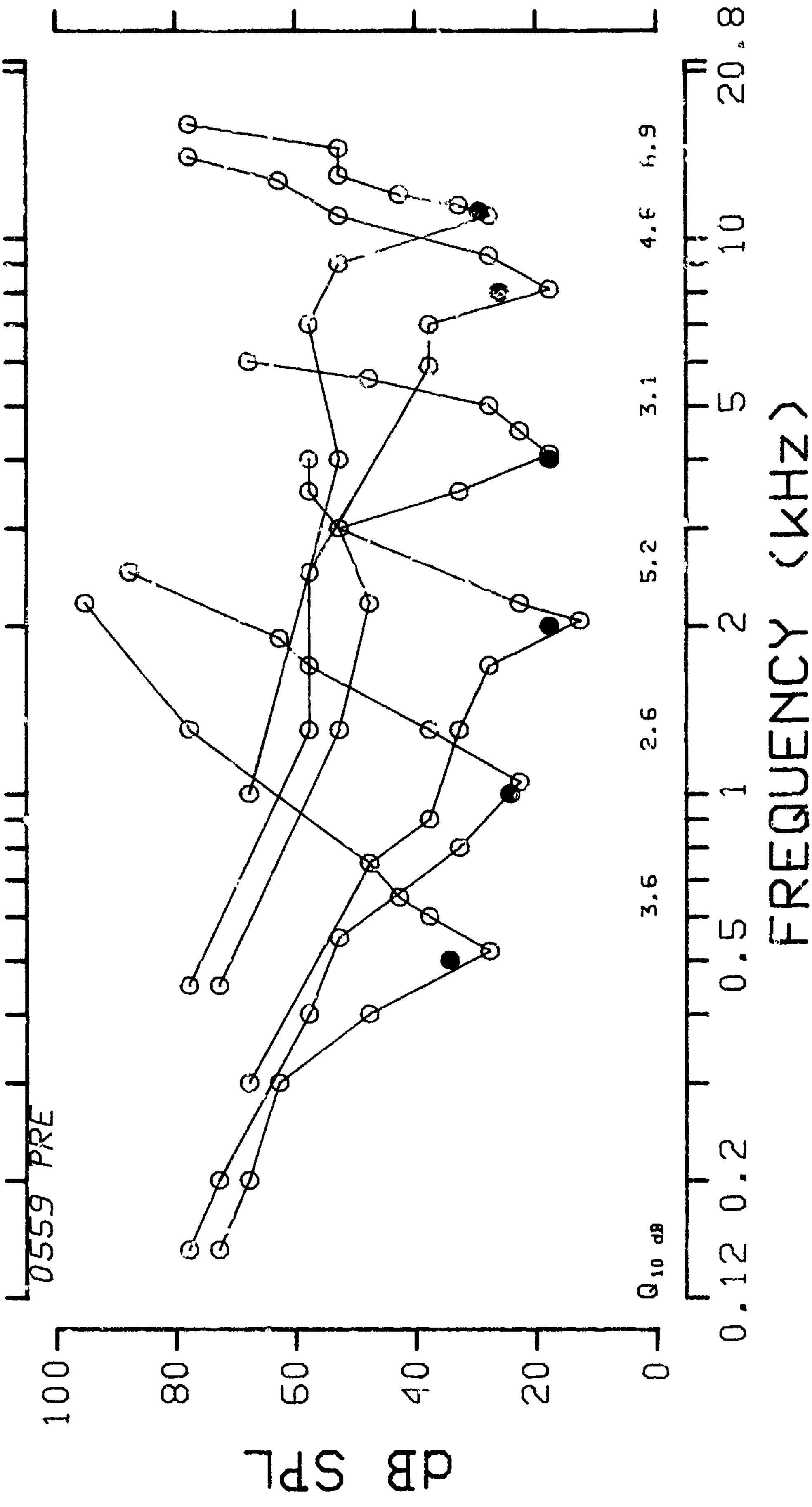

0557 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
2.4
2.7
4.0
3.5
8.9
3.8
0.12 0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

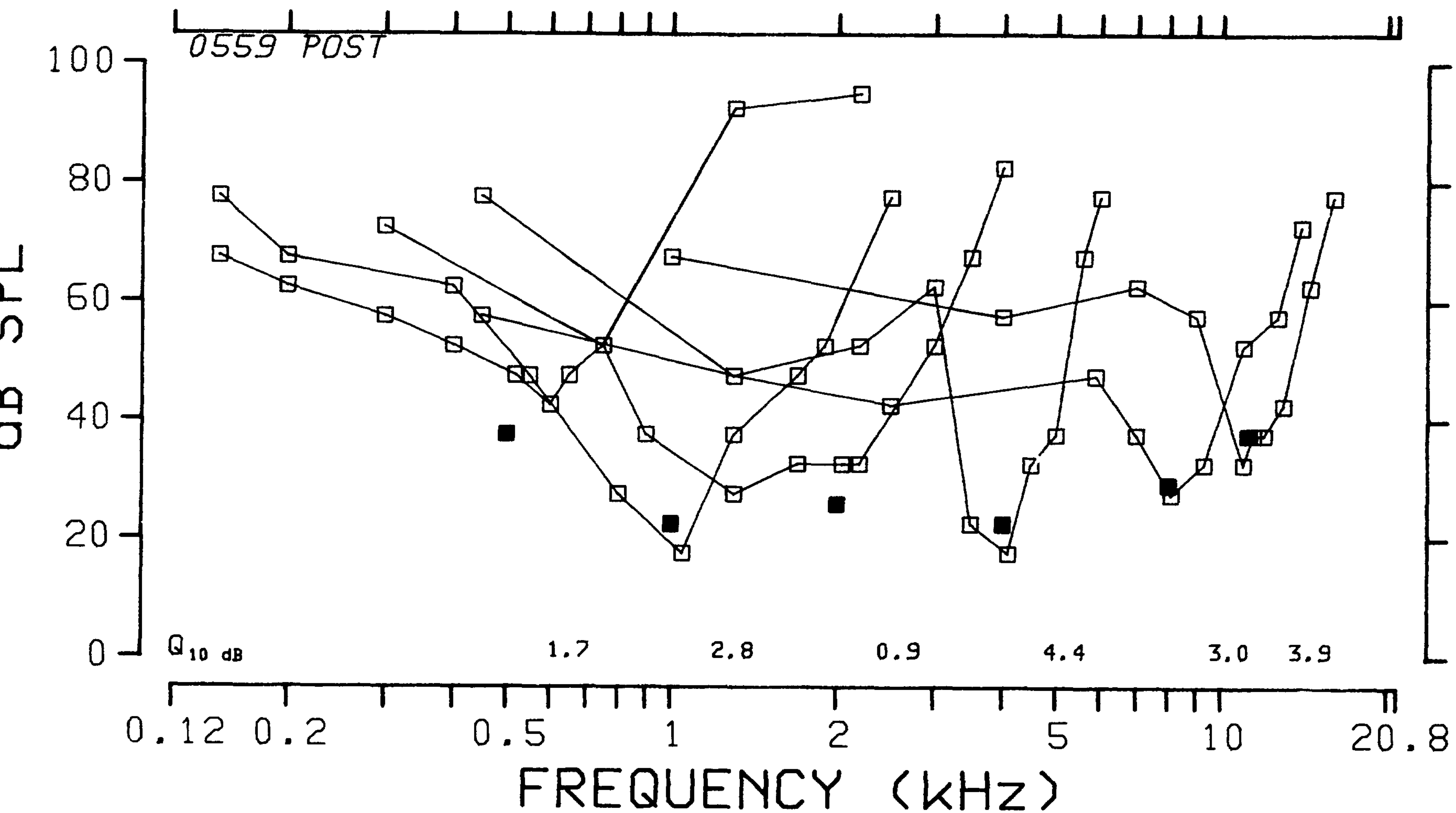

0557 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.7
3.6
3.3
3.2
7.3
3.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)



0558 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
1.9
2.1
1.7
3.0
5.3
3.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0558 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.5
2.6
3.2
2.8
4.3
10.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0559 PRE
FREQUENCY (kHz)
dB SPL
0
20
40
60
80
100
0.12
0.2
0.5
1
2
5
10
20.8
$Q_{10\ dB}$
3.6
2.6
5.2
3.1
4.6


0559 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.7
2.8
0.9
4.4
3.0
3.9
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

150 dB 100X 1/10M

TOTAL NUMBER OF COCHLEAR SENSORY CELLS MISSING

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0553	7	37	19	48	104
0556	8	74	40	51	165
0557	17	23	35	56	114
0558	0	27	110	113	250
0559	4	27	56	55	138
GROUP MEAN	7				154
S.D.	6				59
S.E.	3				26

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

	OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	OUTER HAIR CELLS
GROUP MEANS			
	0.125 kHz	0.0	64.8
	0.25 kHz	1.2	23.0
	0.5 kHz	1.2	18.6
	1 kHz	0.8	15.2
	2 kHz	0.6	8.2
	4 kHz	2.0	10.8
	8 kHz	0.6	6.2
	16 kHz	0.8	7.4
STANDARD DEVIATIONS			
	0.125 kHz	0.0	49.0
	0.25 kHz	1.3	15.6
	0.5 kHz	1.8	10.2
	1 kHz	0.8	15.2
	2 kHz	0.5	4.6
	4 kHz	2.9	2.8
	8 kHz	0.9	3.3
	16 kHz	1.3	2.7

150 dB 100X 1/10M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

CHINCHILLA 0553

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
0.125 kHz	0	7	10	29	46	0	1
0.25 kHz	2	5	1	7	13	0	0
0.5 kHz	2	4	3	1	8	1	0
1 kHz	0	3	2	2	7	0	0
2 kHz	1	2	0	2	4	0	0
4 kHz	1	8	0	5	13	0	0
8 kHz	0	4	1	1	6	0	0
16 kHz	1	4	2	1	7	0	0
TOTALS	7	37	19	48	104	1	1

CHINCHILLA 0556

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
0.125 kHz	0	11	10	16	37	0	0
0.25 kHz	1	3	2	6	11	0	0
0.5 kHz	0	12	6	10	28	2	0
1 kHz	1	23	10	9	42	0	1
2 kHz	1	10	4	1	15	0	0
4 kHz	0	7	3	4	14	0	0
8 kHz	2	6	3	3	12	0	0
16 kHz	3	2	2	2	6	0	0
TOTALS	8	74	40	51	165	2	1

CHINCHILLA 0557

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
0.125 kHz	0	5	9	26	40	0	1
0.25 kHz	3	9	8	9	26	1	2
0.5 kHz	4	3	7	3	13	0	0
1 kHz	1	1	6	4	11	0	0
2 kHz	1	2	1	5	8	0	0
4 kHz	7	0	3	5	8	0	0
8 kHz	1	1	0	3	4	0	0
16 kHz	0	2	1	1	4	0	0
TOTALS	17	23	35	56	114	1	3

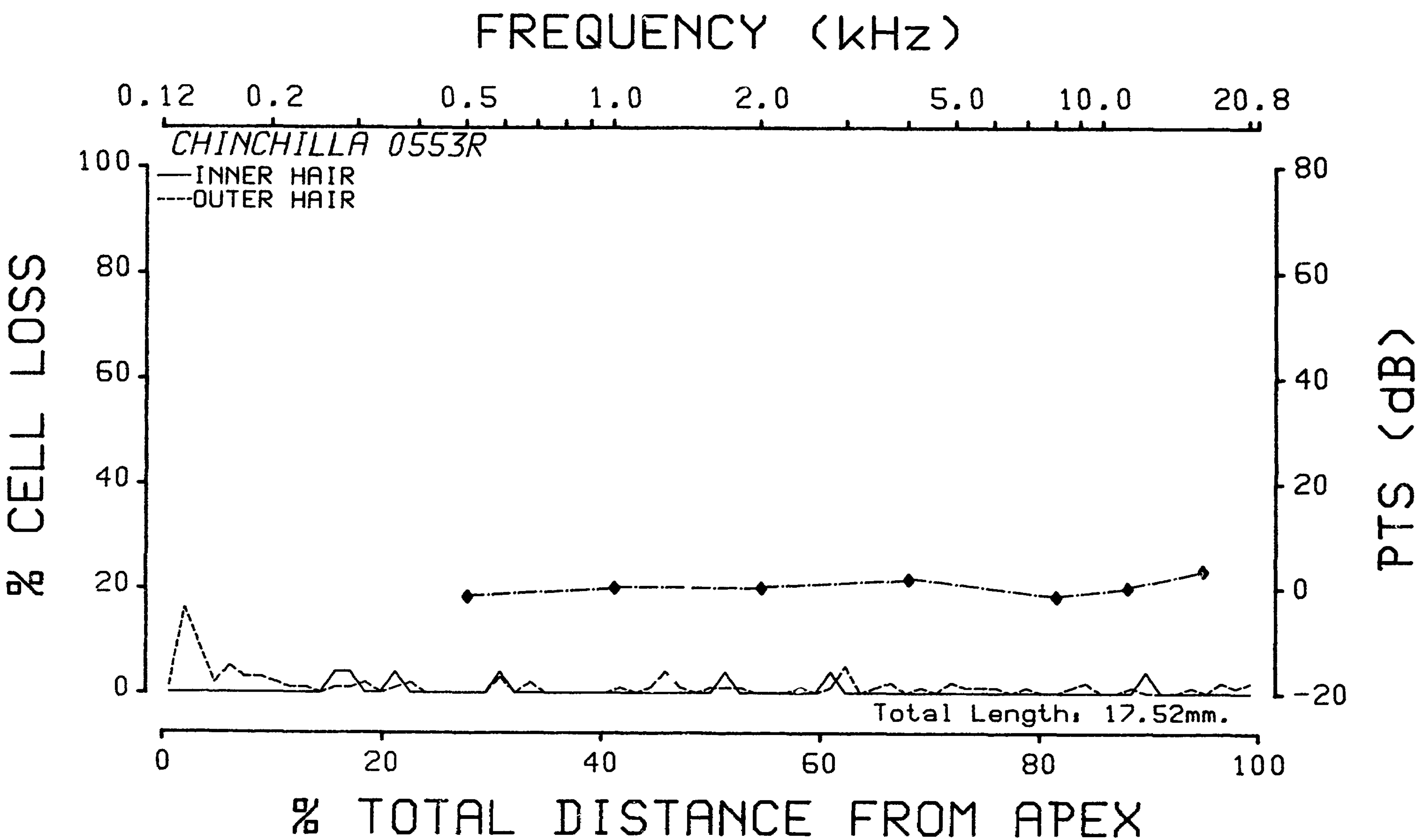
150 dB 100X 1/10M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

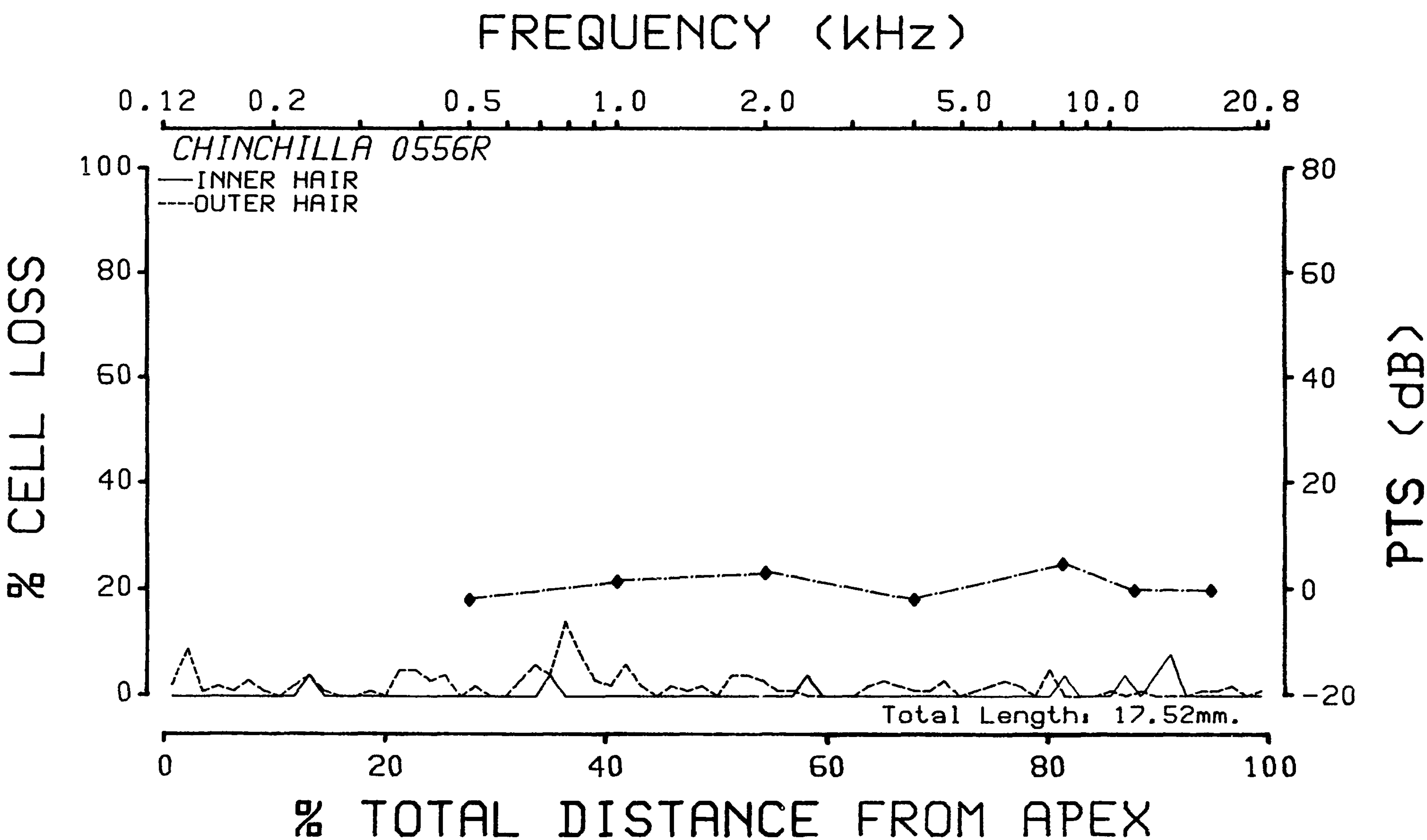
	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0558							
0.125 kHz	0	15	88	49	152	0	1
0.25 kHz	0	1	6	42	49	0	0
0.5 kHz	0	2	3	8	13	0	0
1 kHz	0	2	2	1	5	0	0
2 kHz	0	3	1	6	10	0	0
4 kHz	0	2	3	3	8	0	0
8 kHz	0	2	2	0	4	0	0
16 kHz	0	0	5	4	9	0	0
TOTALS	0	27	110	113	250	0	1
CHINCHILLA 0559							
0.125 kHz	0	1	23	25	49	0	5
0.25 kHz	0	5	3	8	16	0	1
0.5 kHz	0	9	16	5	31	0	0
1 kHz	2	2	7	2	11	0	0
2 kHz	0	1	0	3	4	0	0
4 kHz	2	3	3	5	11	0	0
8 kHz	0	1	1	3	5	0	0
16 kHz	0	5	3	3	11	0	0
TOTALS	4	27	56	55	138	0	6
GROUP MEANS							
0.125 kHz	0.0	7.8	28.0	29.0	64.8	0.0	1.6
0.25 kHz	1.2	4.6	4.0	14.4	23.0	0.2	0.6
0.5 kHz	1.2	6.0	7.0	5.6	18.6	0.6	0.0
1 kHz	0.8	6.2	5.4	3.6	15.2	0.0	0.2
2 kHz	0.6	3.6	1.2	3.4	8.2	0.0	0.0
4 kHz	2.0	4.0	2.4	4.4	10.3	0.0	0.0
8 kHz	0.6	2.8	1.4	2.0	6.2	0.0	0.0
16 kHz	0.8	2.6	2.6	2.2	7.4	0.0	0.0
TOTALS	7.2	37.6	52.0	64.6	154.2	0.8	2.4

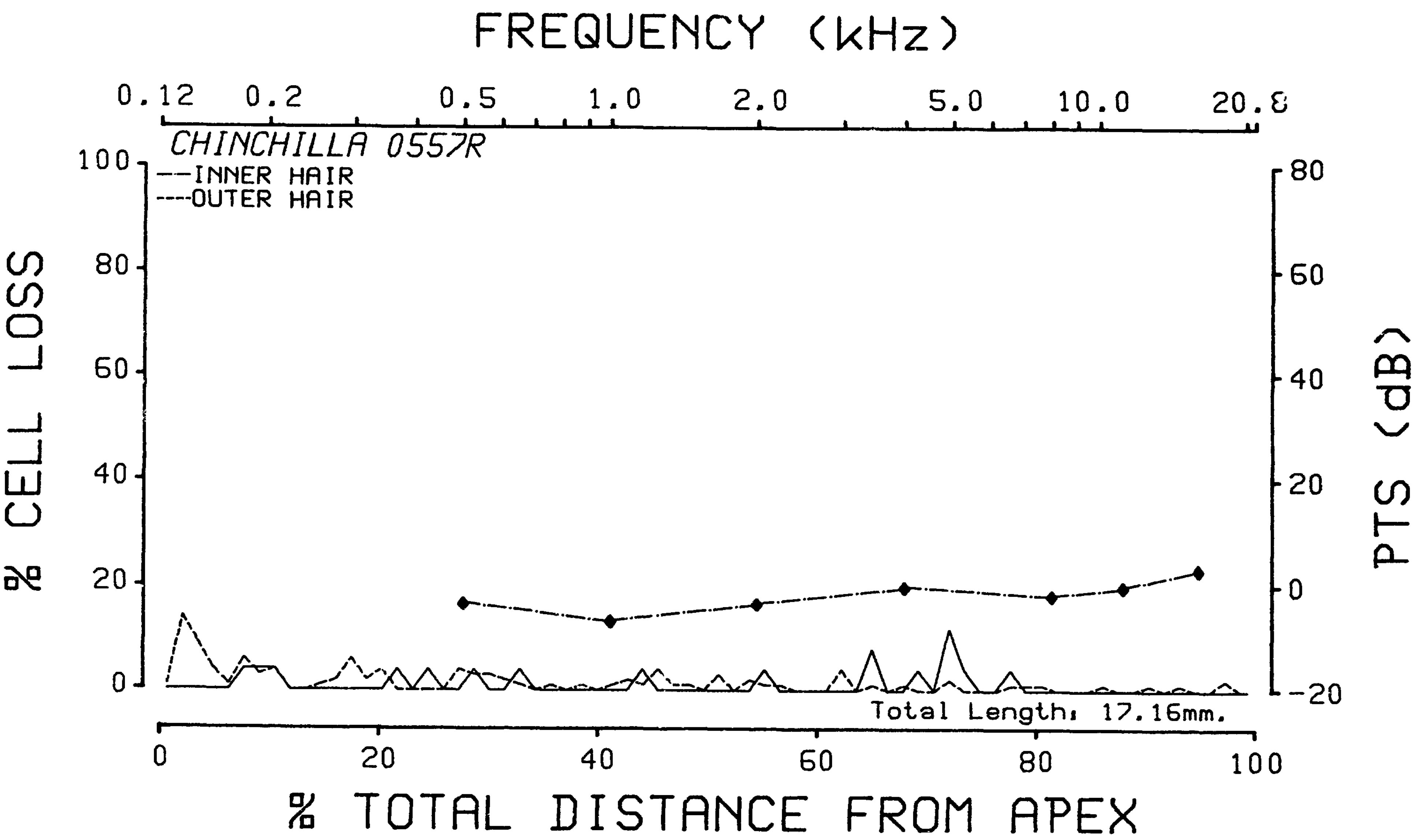
Cochleograms and PTS Audiograms

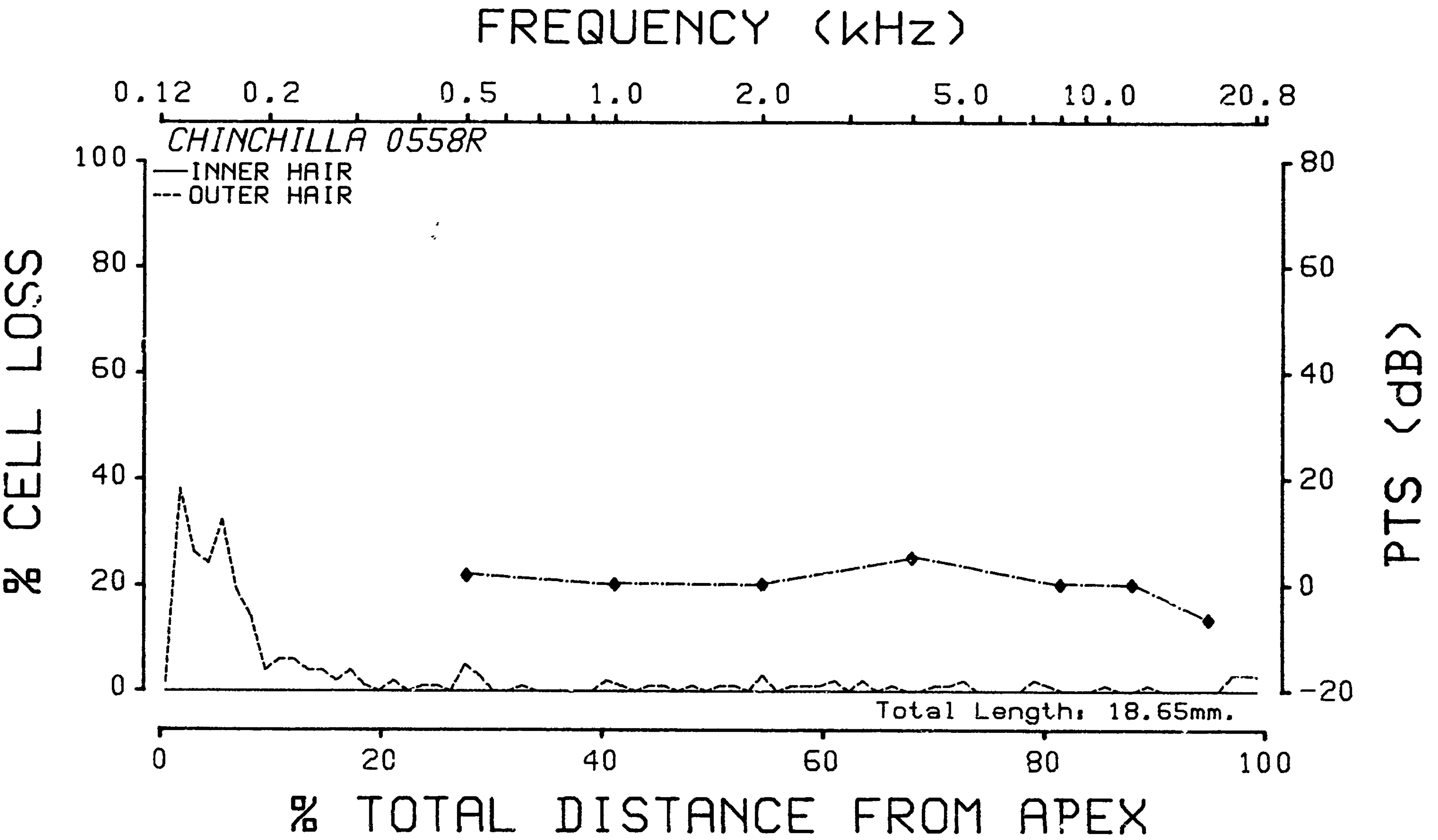
for Individual Animals

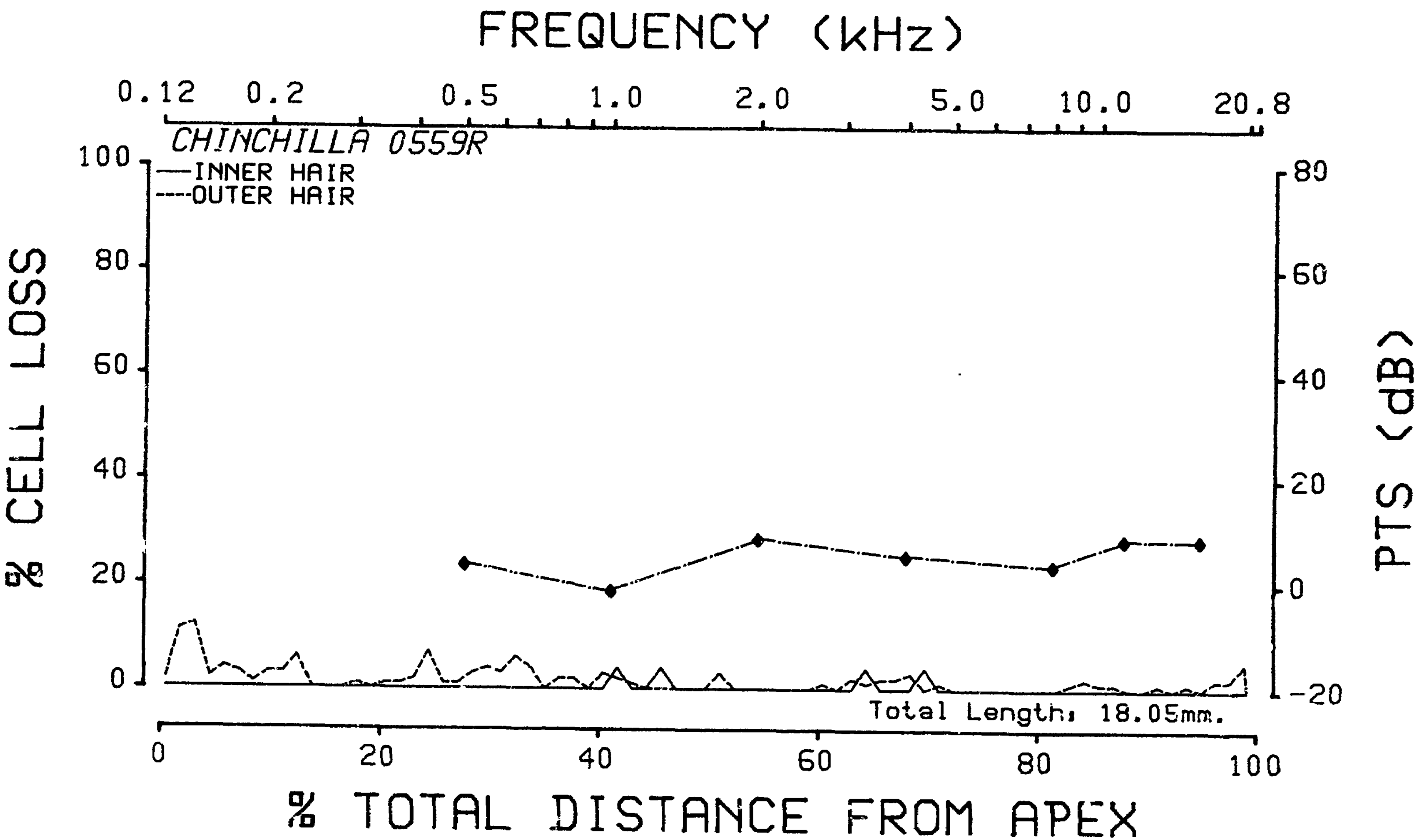


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0553R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.52mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0556R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.52mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0557R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.16mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
CHINCHILLA 0558R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100 80 60 40 20 0
PTS (dB)
80 60 40 20 0 -20
Total Length: 18.65mm.
0 20 40 60 80 100
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0559R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.05mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

Summary Data for the Group Exposed to:

160 dB, 10X, 10/M

Animal #

0515	-	Completed the Entire Protocol except Post-Exposure tuning curves at 2.0 and 11.2 kHz probe frequencies
0517	-	Completed the Entire Protocol
0518	-	Completed the Entire Protocol
0522	-	Completed the Entire Protocol
0523	-	Completed the Entire Protocol

160 dB 10X 10/M

PRE-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0515	20.8	7.5	12.5	0.8	17.5	19.2	20.8
0517	22.5	5.8	10.8	0.8	14.2	12.5	24.2
0518	17.5	9.2	14.2	2.5	14.2	2.5	19.2
0522	17.5	4.2	12.5	-0.8	10.8	12.5	17.5
0523	15.8	-2.5	4.2	-0.8	10.8	9.2	15.8
Mean	18.8	4.8	10.8	0.5	13.5	11.2	19.5
S.D.	2.7	4.5	3.9	1.4	2.8	6.1	3.2

POST-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0515	19.2	9.2	14.2	12.5	24.2	22.5	29.2
0517	17.5	10.8	15.8	2.5	19.2	15.8	17.5
0518	22.5	10.8	15.8	10.8	19.2	0.8	27.5
0522	30.8	39.2	35.8	17.5	14.2	14.2	22.5
0523	32.5	34.2	39.2	22.5	35.8	40.8	54.2
Mean	24.5	20.8	24.2	13.2	22.5	18.8	30.2
S.D.	6.8	14.6	12.3	7.5	8.3	14.6	14.2

PERMANENT THRESHOLD SHIFT (dB)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0515	-1.7	1.7	1.7	11.7	6.7	3.3	8.3
0517	-5.0	5.0	5.0	1.7	5.0	3.3	-6.7
0518	5.0	1.7	1.7	8.3	5.0	-1.7	8.3
0522	13.3	35.0	23.3	18.3	3.3	1.7	5.0
0523	16.7	36.7	35.0	23.3	25.0	31.7	38.3
Mean	5.7	16.0	13.3	12.7	9.0	7.7	10.7
S.D.	9.3	18.2	15.1	8.5	9.0	13.6	16.6

160 dB 10X 10/M

TEMPORARY THRESHOLD SHIFT (dB)

Frequency 0.5 kHz

Animal\Hr	0	2	8	24	240	Max
0515	11.7	6.7	1.7	1.7	1.7	11.7
0517	25.0	10.0	10.0	10.0	5.0	25.0
0518	10.0	5.0	5.0	0.0	5.0	10.0
0522	45.0	77.5*	65.0	40.0	20.0	77.5
0523	31.7	71.7	56.7	61.7	26.7	71.7
Mean	24.7	34.2	27.7	22.7	11.7	39.2
S.D.	14.6	37.0	30.6	27.1	11.0	32.9

Frequency 2.0 kHz

Animal\Hr	0	2	8	24	240	Max
0515	40.0	25.0	10.0	10.0	0.0	40.0
0517	26.7	11.7	1.7	1.7	-3.3	26.7
0518	8.3	3.3	3.3	-1.7	3.3	8.3
0522	50.0	75.5*	70.0	40.0	30.0	75.5
0523	48.3	83.8*	83.8*	73.3	43.3	83.8
Mean	34.7	39.9	33.8	24.7	14.7	46.9
S.D.	17.4	37.3	39.8	31.8	20.8	32.1

Frequency 8.0 kHz

Animal\Hr	0	2	8	24	240	Max
0515	45.0	10.0	10.0	5.0	0.0	45.0
0517	53.3	33.3	33.3	8.3	23.3	53.3
0518	18.3	3.3	8.3	3.3	3.3	18.3
0522	36.7	76.7	76.7	31.7	1.7	76.7
0523	26.7	76.7	71.7	61.7	36.7	76.7
Mean	36.0	40.0	40.0	22.0	13.0	54.0
S.D.	14.0	35.3	32.8	25.0	16.3	24.4

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 10/M

Probe Frequency: 0.5 kHz

Masker (kHz):		0.150	0.200	0.300	0.400	0.520	0.500	0.650	0.750	1.300	2.200
Animal	(Q-10 dB)					Pre-Exposure					
0515	(1.61)	82.5	72.5	62.5	57.5	47.5	47.5	42.5	47.5	67.5	92.5
0517	(2.09)	77.5	67.5	57.5	47.5	37.5	42.5	47.5	47.5	92.5	95.0*
0518	(1.29)	67.5	62.5	52.5	42.5	37.5	37.5	37.5	47.5	67.5	95.0*
0522	(2.44)	77.5	67.5	57.5	52.5	37.5	42.5	47.5	52.5	95.0*	95.0*
0523	(1.49)	72.5	67.5	57.5	47.5	37.5	42.5	42.5	47.5	72.5	95.0*
Mean	(1.78)	75.5	67.5	57.5	49.5	39.5	42.5	43.5	48.5	79.0	94.5
S.D.	(0.47)	5.7	3.5	3.5	5.7	4.5	3.5	4.2	2.2	13.6	1.1
Animal	(Q-10 dB)					Post-Exposure					
0515	(3.08)	67.5	67.5	52.5	42.5	42.5	42.5	32.5	37.5	72.5	92.5
0517	(2.41)	77.5	72.5	47.5	42.5	37.5	32.5	42.5	52.5	67.5	95.0*
0518	(1.13)	72.5	57.5	47.5	42.5	42.5	52.5	42.5	52.5	77.5	92.5
0522	(1.13)	72.5	72.5	62.5	57.5	57.5	67.5	72.5	82.5	95.0*	95.0*
0523	(0.96)	77.5	62.5	57.5	52.5	52.5	57.5	72.5	72.5	95.0*	95.0*
Mean	(1.74)	73.5	66.5	53.5	47.5	46.5	50.5	52.5	59.5	81.5	94.0
S.D.	(0.95)	4.2	6.5	6.5	7.1	8.2	13.5	18.7	17.9	12.8	1.4

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 10/M

Probe Frequency: 1.0 kHz

Masker (kHz):		0.150	0.200	0.400	0.550	0.800	1.050	1.300	1.700	1.900	2.500
Animal	(Q-10 dB)					Pre-Exposure					
0515	(2.47)	82.5	72.5	67.5	57.5	47.5	32.5	42.5	52.5	77.5	91.0*
0517	(3.57)	77.5	72.5	57.5	52.5	37.5	17.5	32.5	52.5	62.5	87.5
0518	(2.08)	77.5	77.5	62.5	47.5	32.5	27.5	42.5	57.5	67.5	91.0*
0522	(1.65)	82.5	77.5	57.5	47.5	37.5	32.5	42.5	57.5	91.0*	91.0*
0523	(3.57)	72.5	72.5	52.5	47.5	37.5	17.5	32.5	47.5	52.5	67.5
Mean	(2.67)	78.5	74.5	59.5	50.5	38.5	25.5	38.5	53.5	70.2	85.6
S.D.	(0.87)	4.2	2.7	5.7	4.5	5.5	7.6	5.5	4.2	14.7	10.2
Animal	(Q-10 dB)					Post-Exposure					
0515	(1.91)	77.5	72.5	62.5	52.5	37.5	27.5	32.5	67.5	82.5	91.0*
0517	(3.13)	82.5	72.5	57.5	57.5	37.5	22.5	37.5	67.5	82.5	91.0*
0518	(1.55)	82.5	77.5	52.5	57.5	32.5	27.5	32.5	47.5	52.5	77.5
0522	(0.85)	92.5	88.0*	82.5	72.5	72.5	67.5	72.5	77.5	77.5	91.0*
0523	(1.86)	92.5	77.5	77.5	82.5	77.5	67.5	72.5	100.0*	91.0*	91.0*
Mean	(1.86)	85.5	77.6	66.5	64.5	51.5	42.5	49.5	72.0	77.2	88.3
S.D.	(0.83)	6.7	6.3	12.9	12.5	21.6	22.9	21.1	19.1	14.6	6.0

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 10/M

Probe Frequency: 2.0 kHz

Masker (kHz):		0.300	0.750	0.900	1.300	1.700	2.050	2.200	3.000	3.500	4.000
Animal	(Q-10 dB)					Pre-Exposure					
0515	(0.90)	82.5	47.5	42.5	37.5	42.5	37.5	47.5	52.5	72.5	96.0*
0517	(1.14)	77.5	47.5	42.5	37.5	37.5	32.5	32.5	47.5	67.5	82.5
0518	(4.01)	77.5	52.5	42.5	32.5	37.5	17.5	22.5	42.5	42.5	62.5
0522	(2.02)	77.5	67.5	57.5	57.5	42.5	37.5	37.5	57.5	82.5	96.0*
0523	(1.33)	77.5	52.5	42.5	37.5	37.5	32.5	37.5	52.5	77.5	96.0*
Mean	(1.88)	78.5	53.5	45.5	40.5	39.5	31.5	35.5	50.5	68.5	86.6
S.D.	(1.26)	2.2	8.2	6.7	9.7	2.7	8.2	9.1	5.7	15.6	14.7
Animal	(Q-10 dB)					Post-Exposure					
0515	(*****)	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
0517	(2.04)	77.5	47.5	47.5	47.5	42.5	32.5	32.5	47.5	72.5	96.0*
0518	(4.10)	92.5	77.5	67.5	82.5	47.5	37.5	47.5	67.5	82.5	87.5
0522	(0.74)	67.5	62.5	62.5	57.5	62.5	67.5	62.5	72.5	72.5	87.5
0523	(*****)	87.5	82.5	77.5	72.5	82.5	72.5	72.5	67.5	67.5	47.5
Mean	(2.29)	81.2	67.5	63.8	65.0	58.8	52.5	53.8	63.8	73.8	79.6
S.D.	(1.69)	11.1	15.8	12.5	15.5	18.0	20.4	17.5	11.1	6.3	21.8

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 10/M

Probe Frequency: 4.0 kHz

Masker (kHz):		0.450	1.300	2.200	3.000	3.500	4.100	4.500	5.000	5.600	6.000
Animal	(Q-10 dB)					Pre-Exposure					
0515	(4.33)	82.5	62.5	52.5	47.5	42.5	32.5	27.5	42.5	47.5	67.5
0517	(4.10)	72.5	62.5	57.5	47.5	27.5	17.5	27.5	37.5	52.5	62.5
0518	(5.06)	82.5	62.5	52.5	42.5	32.5	17.5	27.5	37.5	47.5	72.5
0522	(2.89)	72.5	52.5	52.5	37.5	22.5	17.5	22.5	32.5	47.5	52.5
0523	(3.53)	72.5	52.5	47.5	47.5	32.5	22.5	27.5	42.5	52.5	57.5
Mean	(3.98)	76.5	58.5	52.5	44.5	31.5	21.5	26.5	38.5	49.5	62.5
S.D.	(0.82)	5.5	5.5	3.5	4.5	7.4	6.5	2.2	4.2	2.7	7.9
Animal	(Q-10 dB)					Post-Exposure					
0515	(4.10)	82.5	57.5	57.5	52.5	37.5	27.5	37.5	42.5	72.5	92.0*
0517	(6.77)	72.5	57.5	52.5	62.5	27.5	12.5	32.5	47.5	62.5	72.5
0518	(2.42)	82.5	62.5	57.5	52.5	37.5	27.5	27.5	32.5	47.5	57.5
0522	(2.58)	77.5	57.5	52.5	52.5	42.5	37.5	37.5	52.5	77.5	72.5
0523	(2.82)	82.5	67.5	62.5	62.5	62.5	47.5	52.5	52.5	72.5	82.5
Mean	(3.74)	79.5	60.5	56.5	56.5	41.5	30.5	37.5	45.5	66.5	75.4
S.D.	(1.82)	4.5	4.5	4.2	5.5	12.9	13.0	9.4	8.4	11.9	12.9

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 10/M

Probe Frequency: 8.0 kHz

Masker (kHz):		0.450	1.300	2.500	5.900	7.000	8.100	9.300	11.000	12.700	14.000
Animal	(Q-10 dB)					Pre-Exposure					
0515	(3.16)	97.5	72.5	67.5	42.5	47.5	37.5	42.5	72.5	100.0*	95.0*
0517	(2.38)	87.5	67.5	47.5	32.5	27.5	22.5	32.5	47.5	62.5	82.5
0518	(2.93)	87.5	67.5	57.5	42.5	42.5	27.5	27.5	47.5	67.5	82.5
0522	(1.61)	72.5	57.5	52.5	37.5	47.5	47.5	37.5	62.5	97.5	95.0*
0523	(5.99)	77.5	67.5	57.5	47.5	52.5	32.5	47.5	57.5	82.5	92.5
Mean	(3.21)	84.5	66.5	56.5	40.5	43.5	33.5	37.5	57.5	82.0	89.5
S.D.	(1.66)	9.7	5.5	7.4	5.7	9.6	9.6	7.9	10.6	17.0	6.5
Animal	(Q-10 dB)					Post-Exposure					
0515	(2.86)	82.5	62.5	67.5	57.5	52.5	42.5	42.5	72.5	92.5	87.5
0517	(4.15)	82.5	62.5	62.5	42.5	42.5	27.5	37.5	82.5	92.5	92.5
0518	(3.85)	92.5	67.5	62.5	52.5	47.5	37.5	32.5	57.5	82.5	95.0*
0522	(2.86)	72.5	57.5	52.5	42.5	42.5	32.5	32.5	62.5	92.5	92.5
0523	(1.31)	77.5	62.5	62.5	52.5	62.5	52.5	62.5	82.5	97.5	95.0*
Mean	(3.01)	81.5	62.5	61.5	49.5	49.5	38.5	41.5	71.5	91.5	92.5
S.D.	(1.11)	7.4	3.5	5.5	6.7	8.4	9.6	12.4	11.4	5.5	3.1

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 10/M

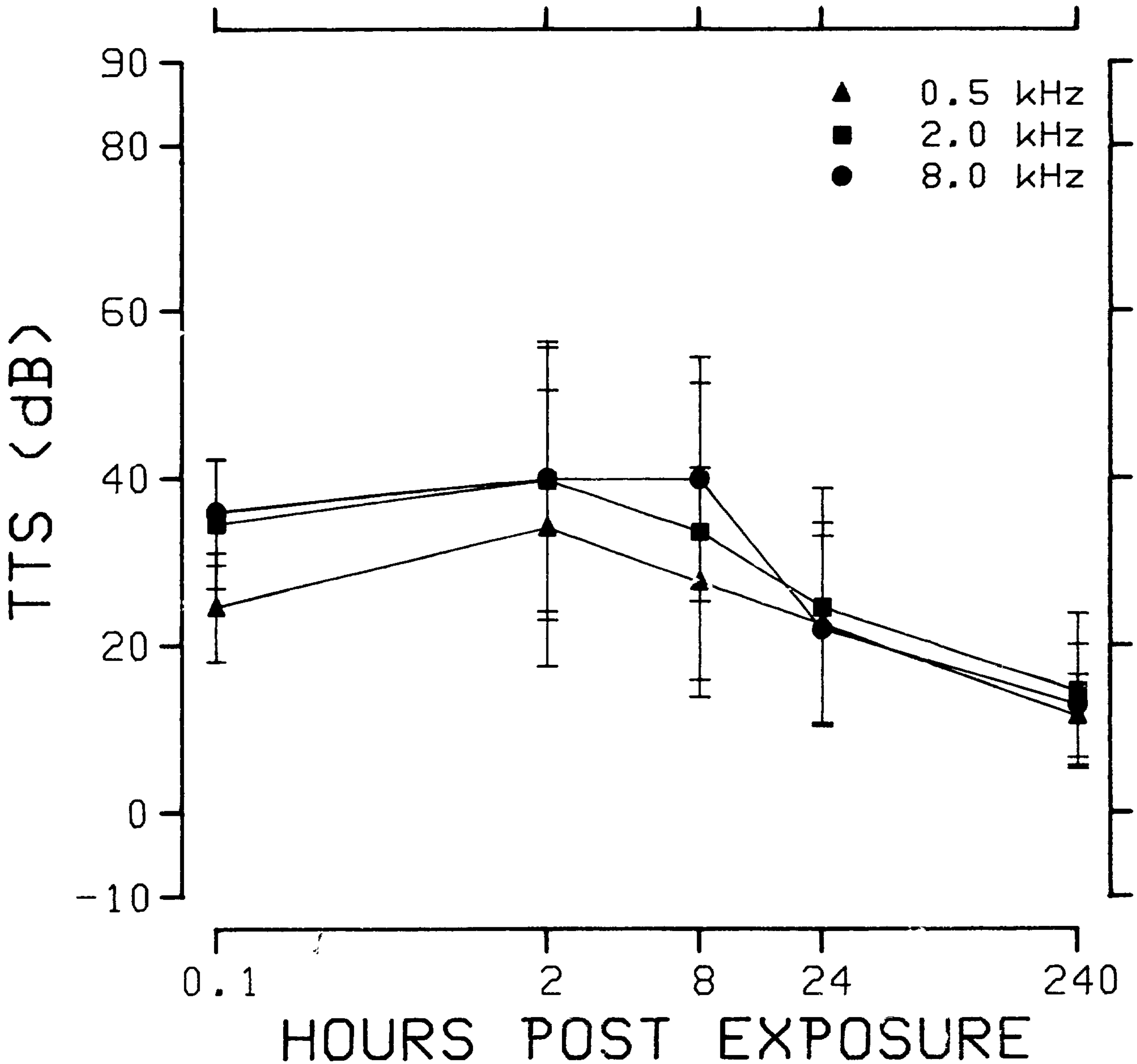
Probe Frequency: 11.2 kHz

Masker (kHz):		1.000	4.000	7.000	9.000	11.000	11.500	12.000	13.000	14.500	16.000
Animal	(Q-10 dB)					Pre-Exposure					
0515	(3.83)	67.5	62.5	62.5	57.5	42.5	37.5	37.5	42.5	67.5	72.5
0517	(3.86)	67.5	52.5	47.5	57.5	32.5	37.5	32.5	42.5	57.5	82.5
0518	(13.72)	67.5	57.5	72.5	52.5	37.5	22.5	32.5	37.5	57.5	72.5
0522	(15.37)	57.5	57.5	67.5	62.5	37.5	27.5	47.5	52.5	67.5	77.5
0523	(4.65)	62.5	52.5	52.5	42.5	37.5	32.5	27.5	27.5	52.5	77.5
Mean	(8.29)	66.5	56.5	60.5	54.5	37.5	31.5	35.5	40.5	60.5	76.5
S.D.	(5.75)	2.2	4.2	10.4	7.6	3.5	6.5	7.6	9.1	6.7	4.2
Animal	(Q-10 dB)					Post-Exposure					
0515	(*****)	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
0517	(3.83)	72.5	67.5	62.5	72.5	42.5	47.5	47.5	47.5	92.5	91.0*
0518	(6.42)	67.5	57.5	82.5	47.5	17.5	22.5	27.5	37.5	47.5	62.5
0522	(4.63)	72.5	57.5	67.5	57.5	37.5	37.5	42.5	57.5	72.5	92.5
0523	(0.70)	82.5	77.5	72.5	72.5	82.5	87.5	77.5	72.5	102.0*	91.0*
Mean	(3.90)	73.8	65.0	71.3	62.5	45.0	48.8	48.8	53.8	78.6	84.3
S.D.	(2.39)	6.3	9.6	8.5	12.2	27.2	27.8	21.0	14.9	24.1	14.5

The Group Mean Recovery Curves

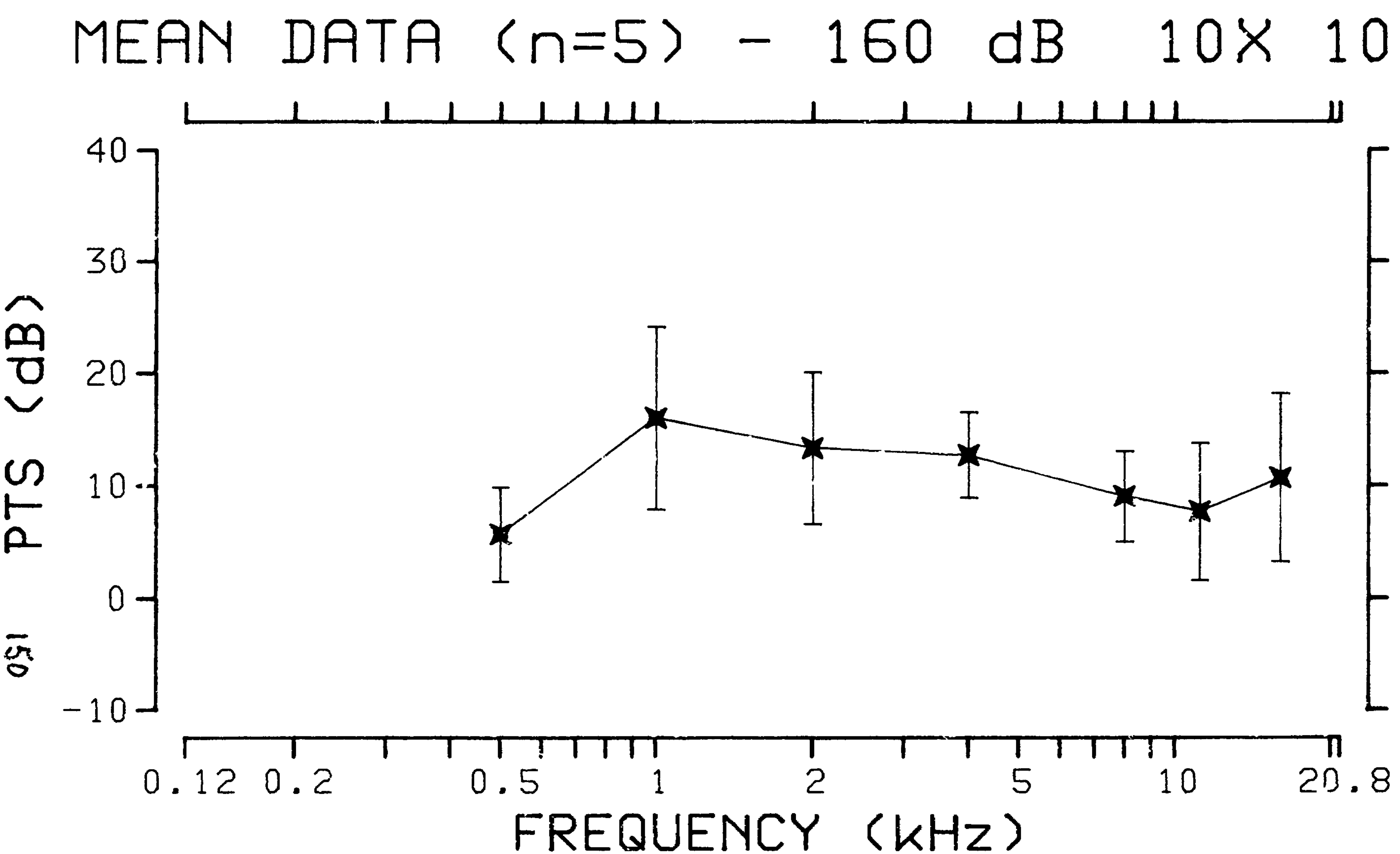
Measured at Three Test Frequencies

MEAN DATA (n=5) - 160 dB 10X 10/M



The Group Mean Permanent Threshold Shift (PTS)

for all Test Frequencies



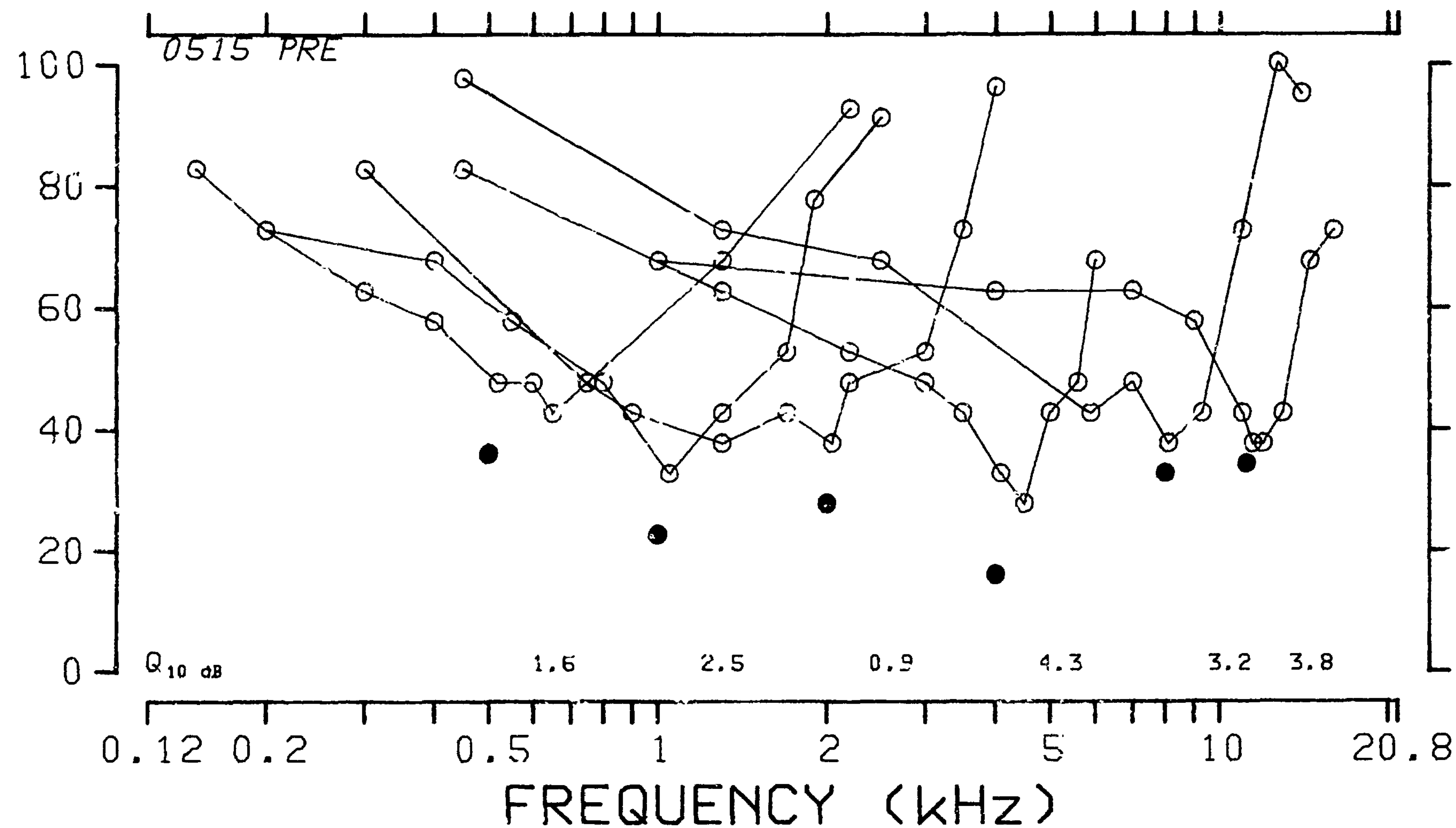
MEAN DATA (n=5) - 160 dB 10X 10/M
PTS (dB)
40
30
20
10
0
-10
0.12 0.2 0.5 1 2 5 10 20.8
FREQUENCY (kHz)

150

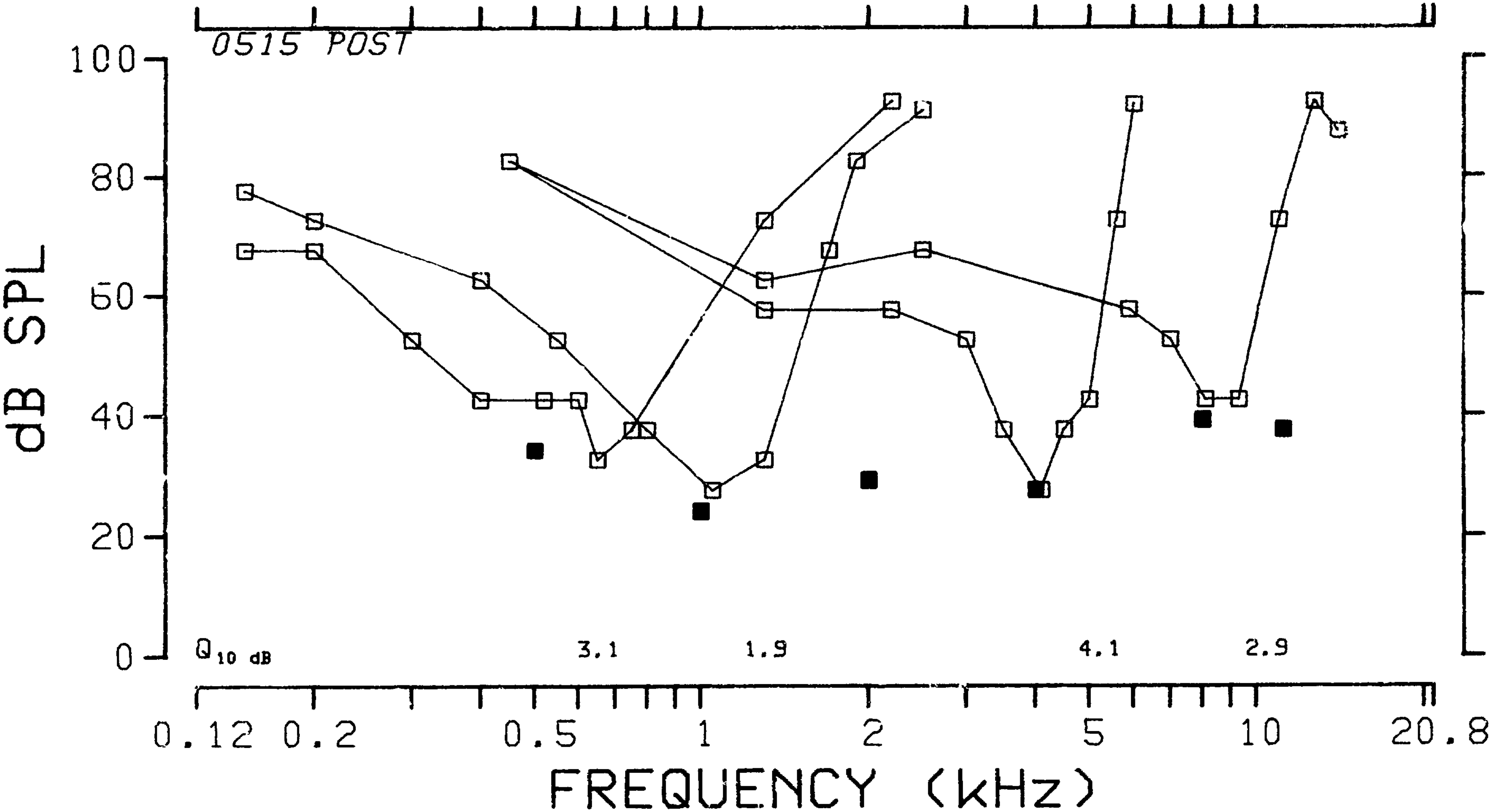
The Pre and Postexposure Tuning Curves for

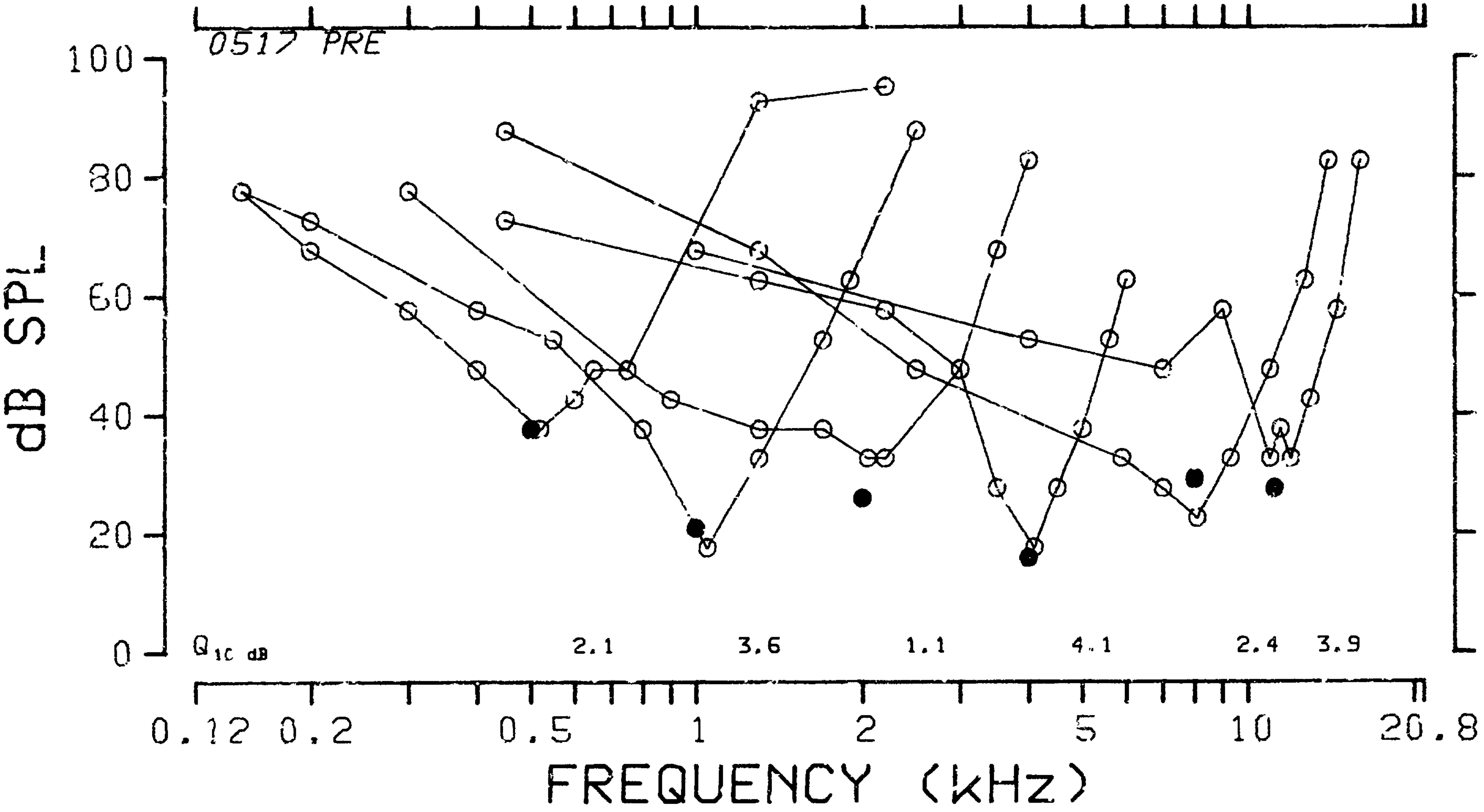
Individual Animals in this Exposure Group.

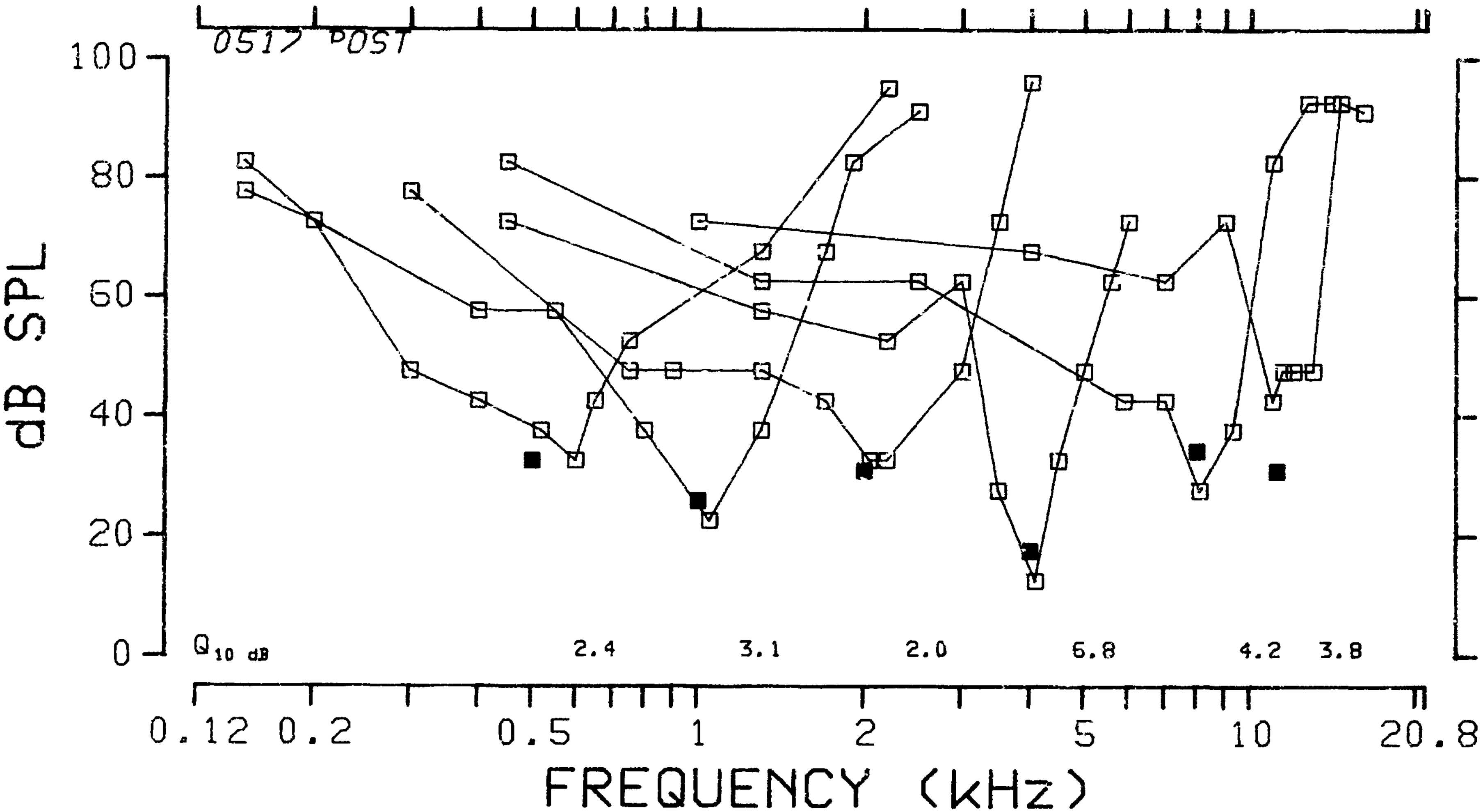
The Solid Symbol represents the intensity of the probe tone.

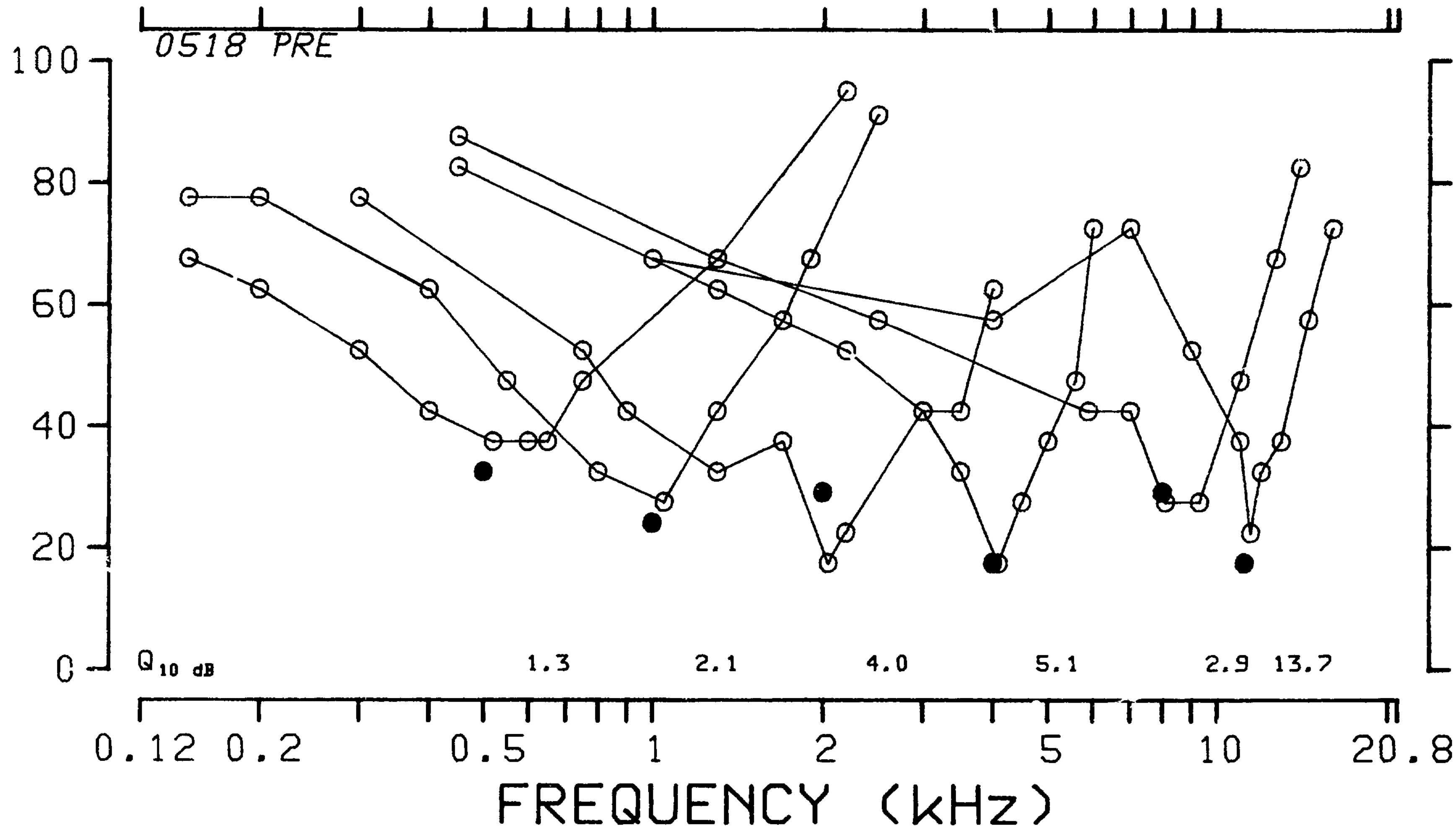


0515 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.6
2.5
0.9
4.3
3.2
3.8
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

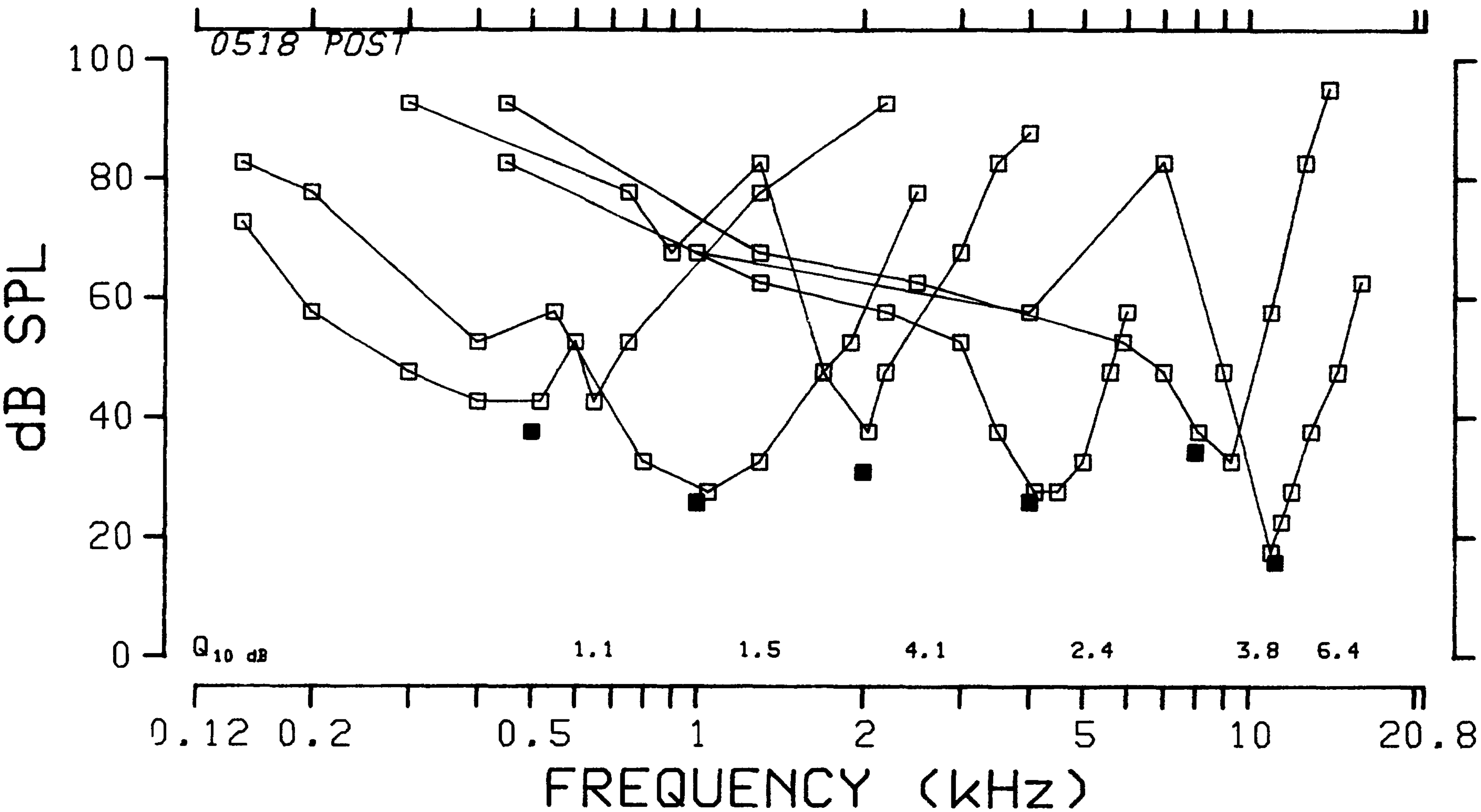

0515 POST
dB SPL
100
80
60
40
20
0
Q10 dB
3.1
1.9
4.1
2.9
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

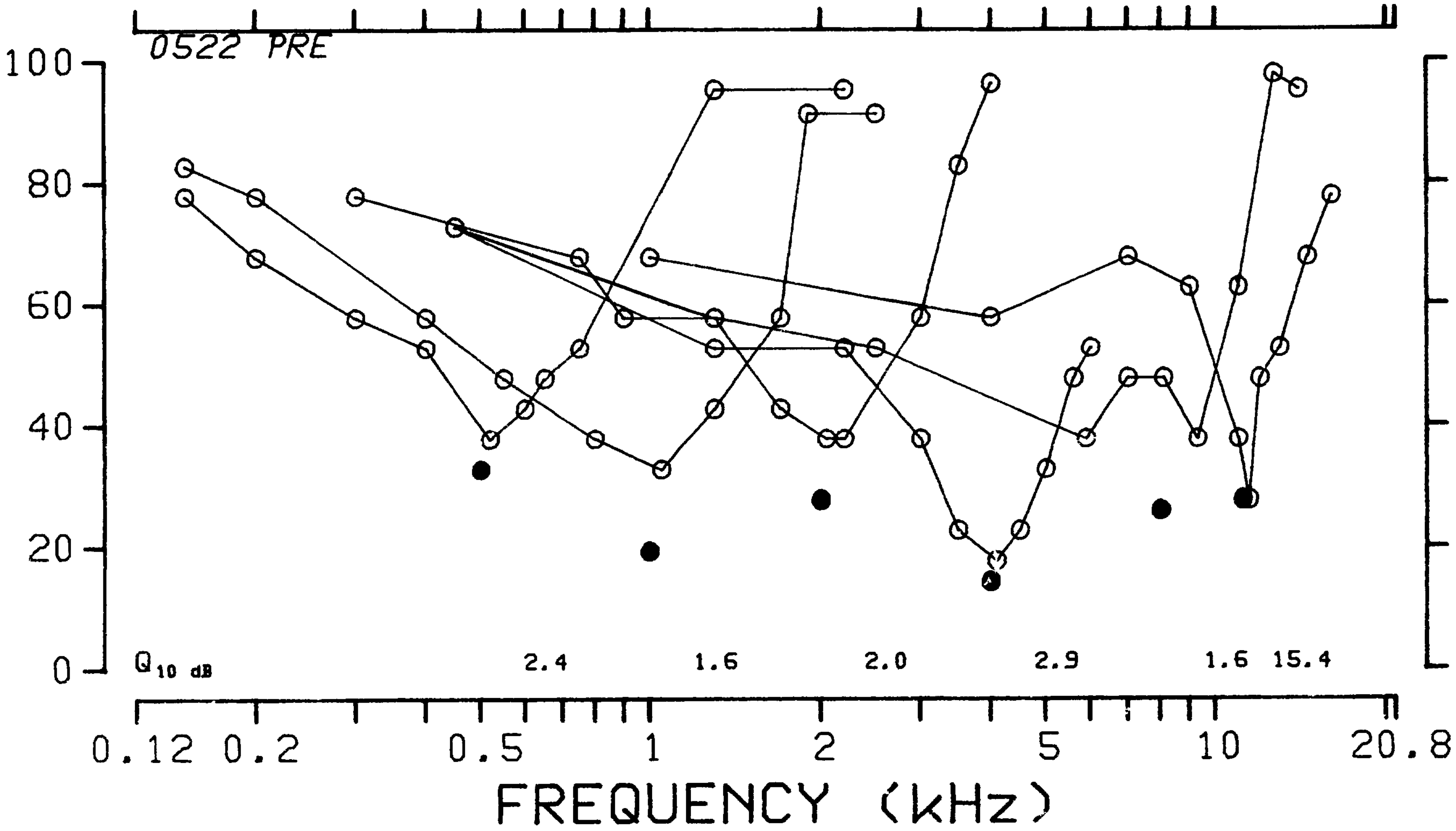

0517 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.1
3.6
1.1
4.1
2.4
3.9
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

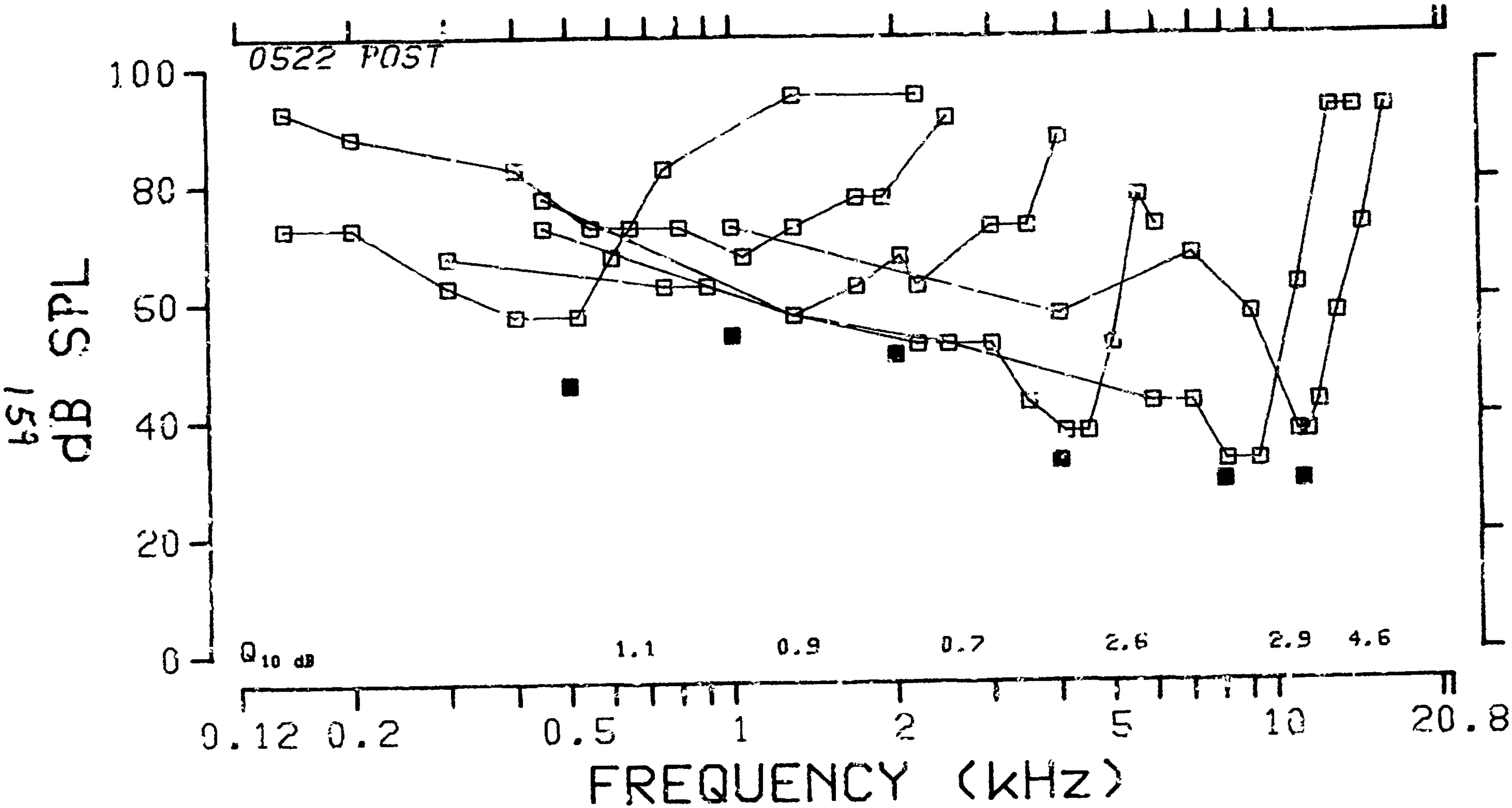

0517 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.4
3.1
2.0
6.8
4.2
3.8
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

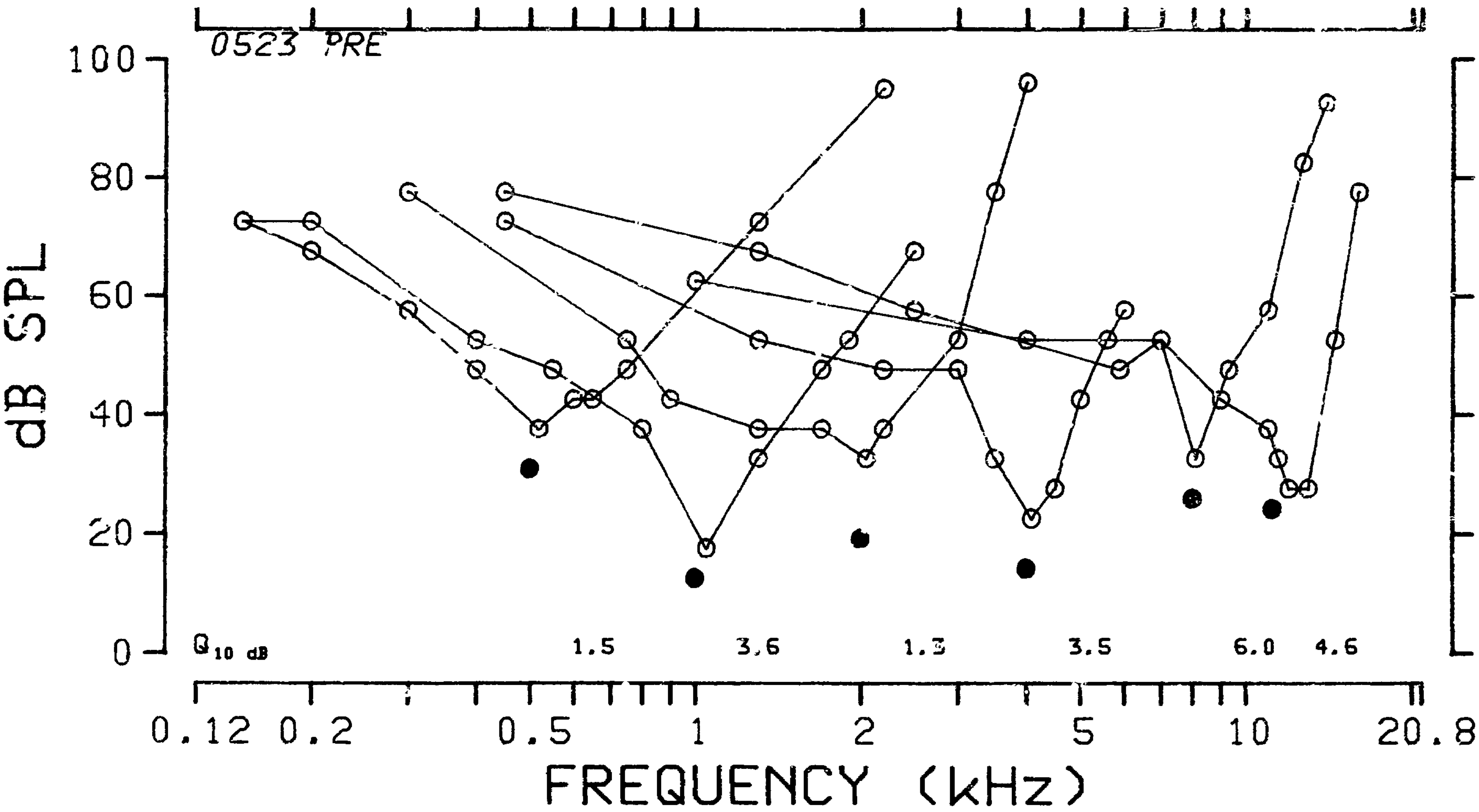


0518 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.3
2.1
4.0
5.1
2.9
13.7
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0518 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.1
1.5
4.1
2.4
3.8
6.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

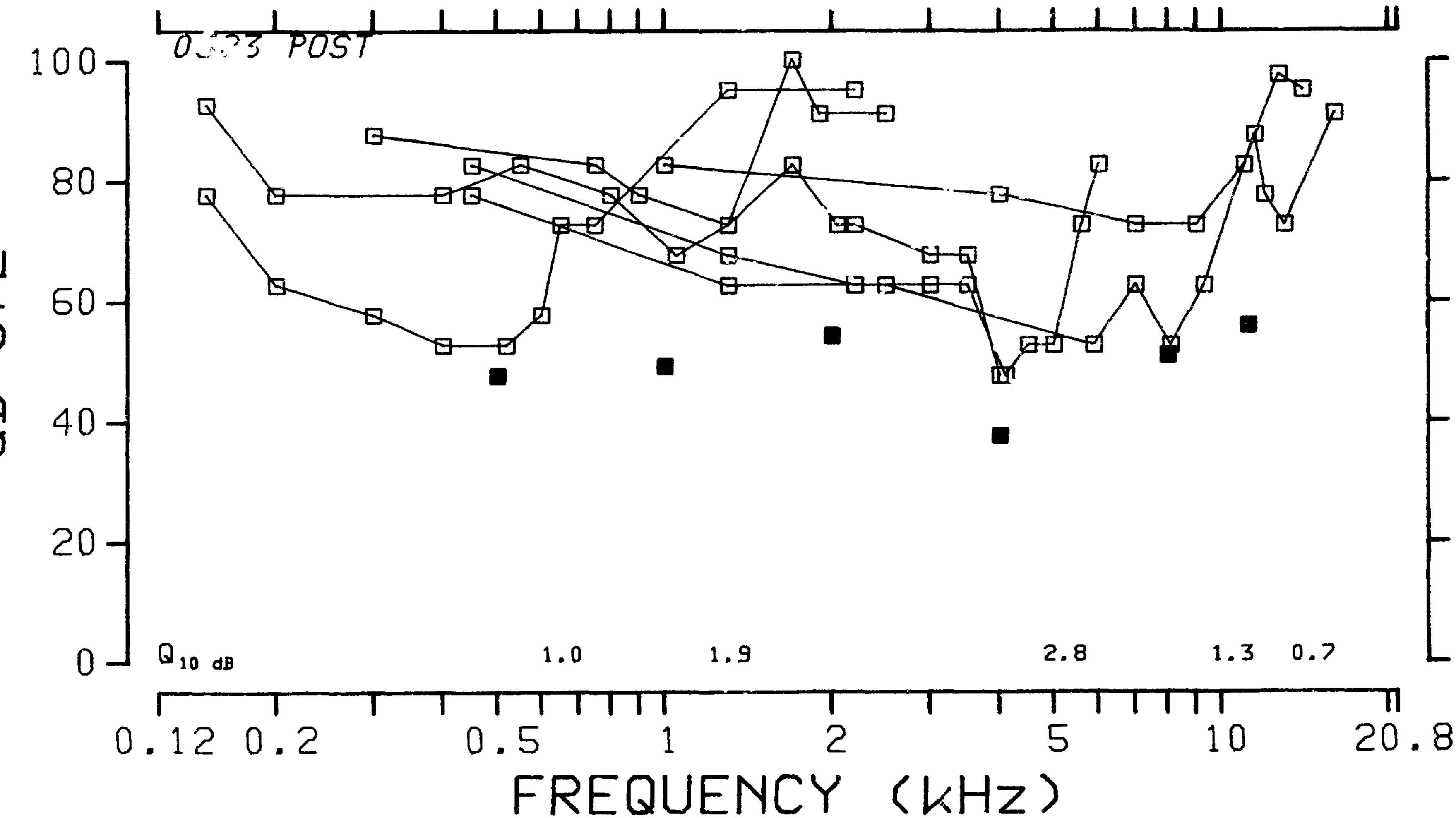

0522 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.4
1.6
2.0
2.9
1.6
15.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0522 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.1
0.9
0.7
2.6
2.9
4.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)



0523 PRE
100
80
60
40
20
0
dB SPL
$Q_{10\ dB}$
1.5
3.6
1.3
3.5
6.0
4.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

160


POST
100
80
60
40
20
0
dB SPL
Q10 dB
1.0
1.9
2.8
1.3
0.7
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

160 dB 10X 10/M

TOTAL NUMBER OF COCHLEAR SENSORY CELLS MISSING

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0515	23	88	147	180	415
0517	19	144	189	200	533
0518	19	41	104	147	292
0522	272	1007	1030	893	2930
0523	258	889	906	791	2586
GROUP MEAN	118				1351
S.D.	134				1293
S.E.	60				578

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

	OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	OUTER HAIR CELLS
GROUP MEANS			
	0.125 kHz	2.4	156.6
	0.25 kHz	1.2	51.2
	0.5 kHz	4.0	110.0
	1 kHz	19.8	343.8
	2 kHz	57.0	383.6
	4 kHz	30.0	273.6
	8 kHz	1.2	20.0
	16 kHz	2.6	12.4
STANDARD DEVIATIONS			
	0.125 kHz	3.4	131.1
	0.25 kHz	1.3	36.3
	0.5 kHz	3.5	166.2
	1 kHz	31.5	429.2
	2 kHz	78.1	497.5
	4 kHz	58.2	364.6
	8 kHz	0.4	12.6
	16 kHz	2.7	6.8

160 dB 10X 10/M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

CHINCHILLA 0515

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
0.125 kHz	8	39	76	50	165	1	6
0.25 kHz	0	6	10	43	59	0	1
0.5 kHz	2	3	11	3	17	0	0
1 kHz	9	31	32	27	90	21	9
2 kHz	1	3	5	26	34	0	0
4 kHz	2	1	6	20	27	0	0
8 kHz	1	4	4	9	17	0	0
16 kHz	0	1	3	2	6	0	0
TOTALS	23	88	147	180	415	22	16

CHINCHILLA 0517

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
0.125 kHz	0	118	124	116	358	0	0
0.25 kHz	0	7	40	63	110	0	0
0.5 kHz	6	6	7	4	17	0	2
1 kHz	3	0	3	3	6	0	0
2 kHz	1	4	4	7	15	0	0
4 kHz	3	1	2	1	4	0	0
8 kHz	1	2	1	2	5	0	0
16 kHz	5	6	8	4	18	0	0
TOTALS	19	144	189	200	533	0	2

CHINCHILLA 0518

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
0.125 kHz	3	15	73	93	181	4	3
0.25 kHz	1	5	4	32	41	0	0
0.5 kHz	3	3	5	4	12	0	0
1 kHz	4	3	8	6	17	0	0
2 kHz	3	4	6	2	12	0	0
4 kHz	3	2	3	4	9	0	0
8 kHz	1	7	4	4	15	1	0
16 kHz	1	2	1	2	5	0	0
TOTALS	19	41	104	147	292	5	3

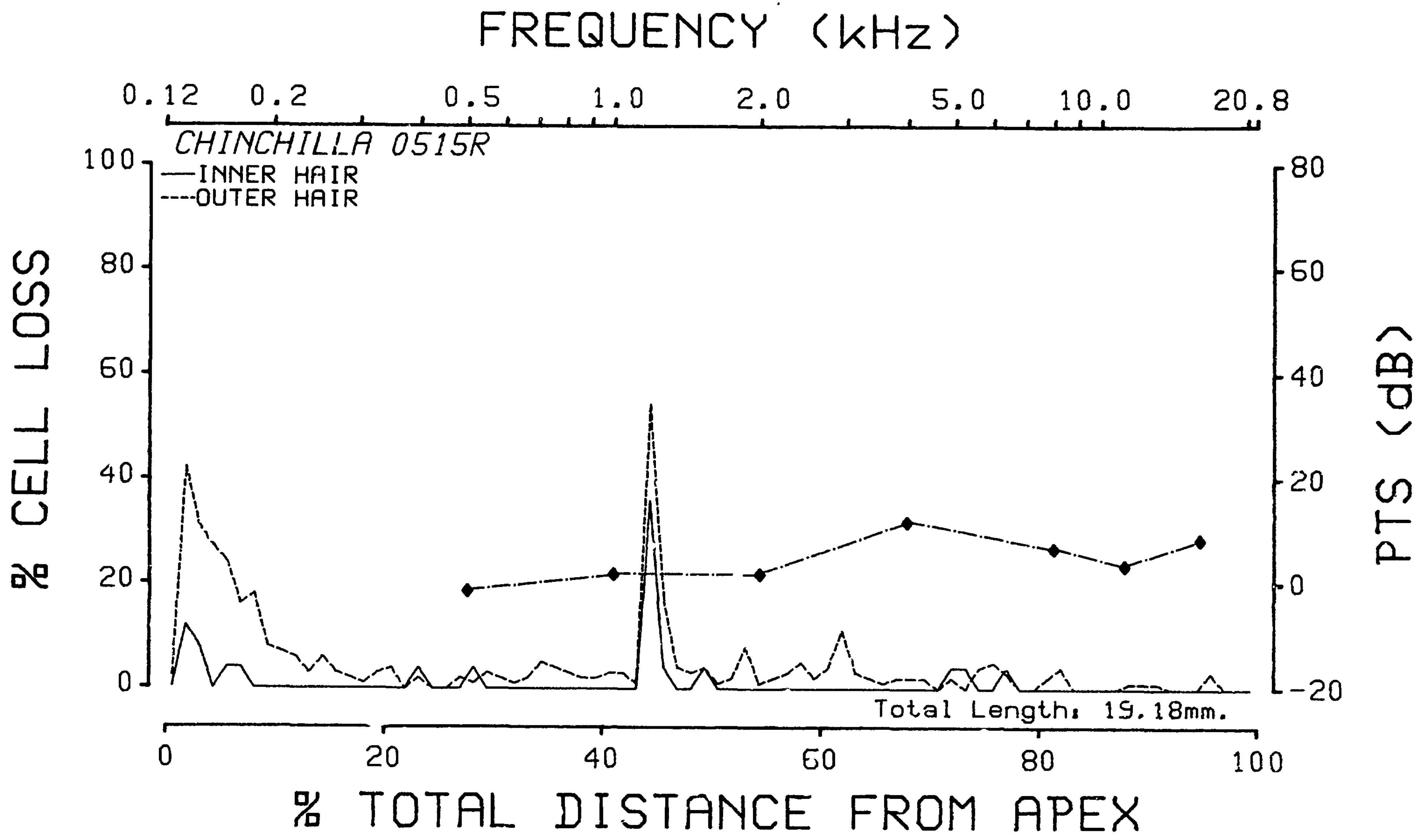
160 dB 10X 10/M

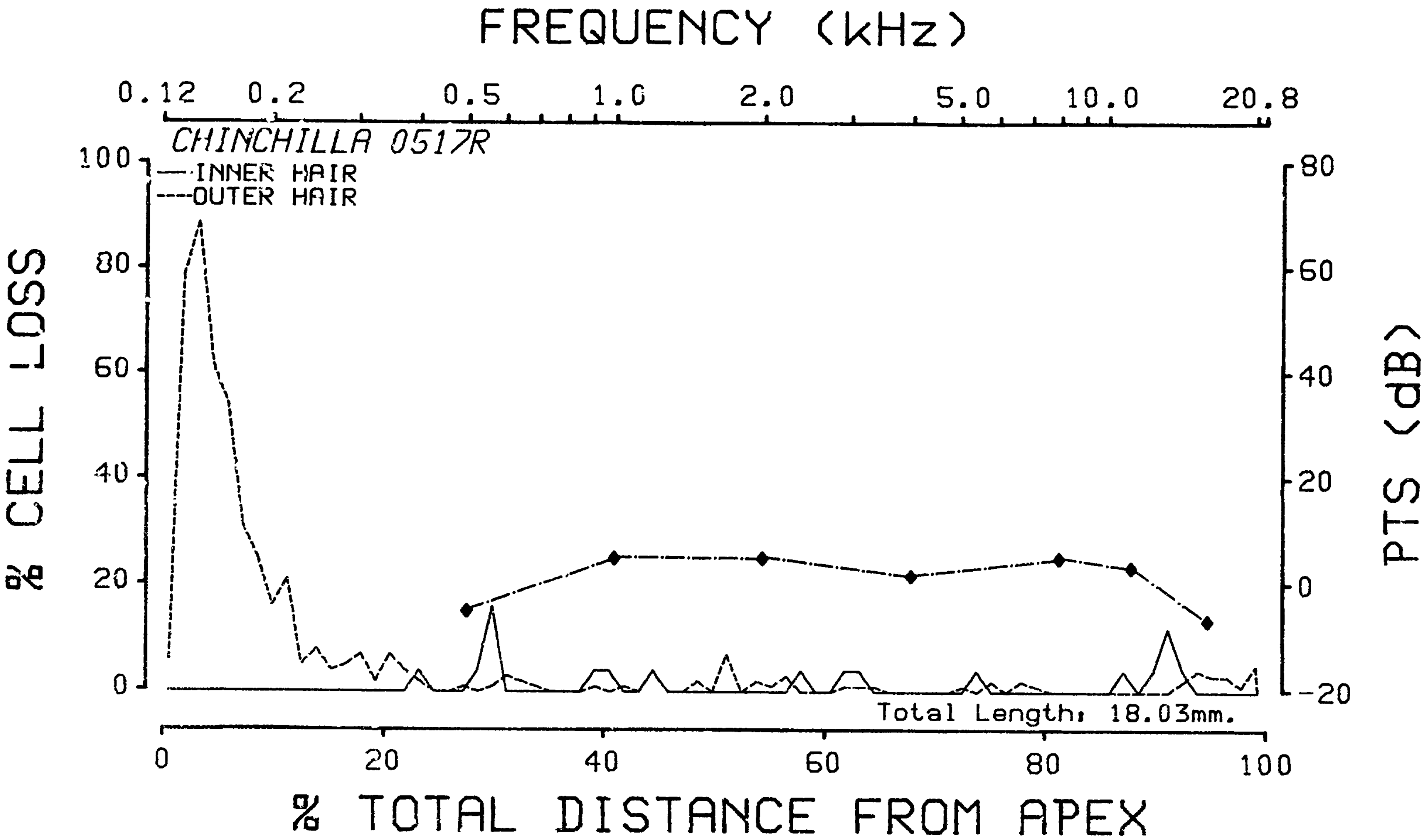
TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0522							
0.125 kHz	1	7	20	20	47	1	0
0.25 kHz	3	4	5	8	17	0	0
0.5 kHz	9	166	149	84	399	0	2
1 kHz	76	309	309	307	925	15	39
2 kHz	167	306	311	310	927	253	169
4 kHz	8	205	215	136	556	0	3
8 kHz	2	7	15	17	39	0	0
16 kHz	6	3	6	11	20	0	0
TOTALS	272	1007	1030	893	2930	269	213
CHINCHILLA 0523							
0.125 kHz	0	0	7	25	32	0	0
0.25 kHz	2	4	6	19	29	0	0
0.5 kHz	0	29	51	25	105	0	2
1 kHz	7	258	240	183	681	5	25
2 kHz	113	310	310	310	930	220	154
4 kHz	134	276	278	218	772	272	171
8 kHz	1	9	9	6	24	0	1
16 kHz	1	3	5	5	13	0	0
TOTALS	258	889	906	791	2586	497	353
GROUP MEANS							
0.125 kHz	2.4	35.8	60.0	60.8	156.6	1.2	1.8
0.25 kHz	1.2	5.2	13.0	33.0	51.2	0.0	0.2
0.5 kHz	4.0	41.4	44.6	24.0	110.0	0.0	1.2
1 kHz	19.8	120.2	118.4	105.2	343.8	8.2	14.6
2 kHz	57.0	125.4	127.2	131.0	383.6	94.6	64.6
4 kHz	30.0	97.0	100.8	75.8	273.6	54.4	34.8
8 kHz	1.2	5.8	6.6	7.6	20.0	0.2	0.2
16 kHz	2.6	3.0	4.6	4.8	12.4	0.0	0.0
TOTALS	118.2	433.8	475.2	442.2	1351.2	158.6	117.4

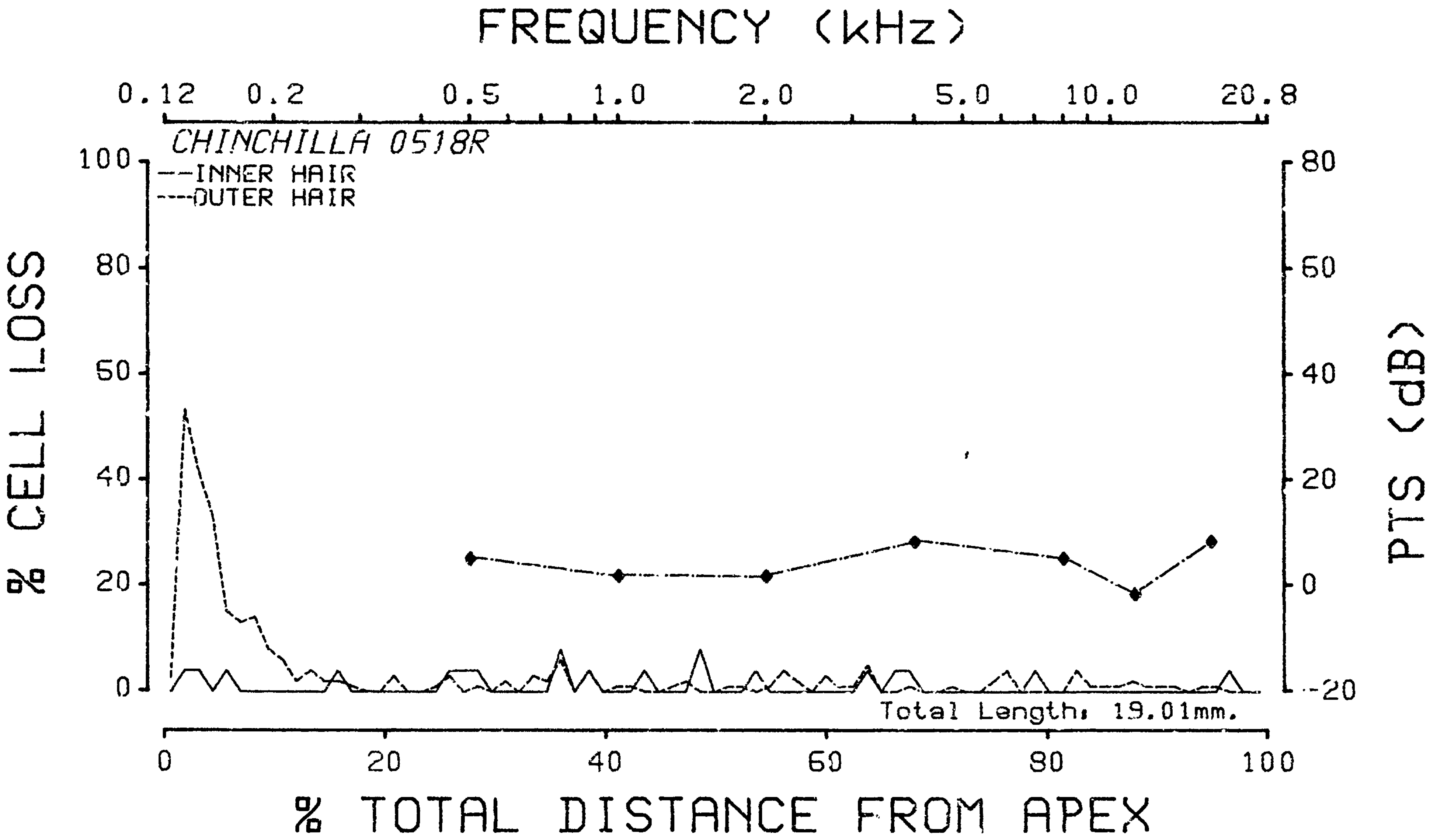
Cochleograms and PTS Audiograms

for Individual Animals

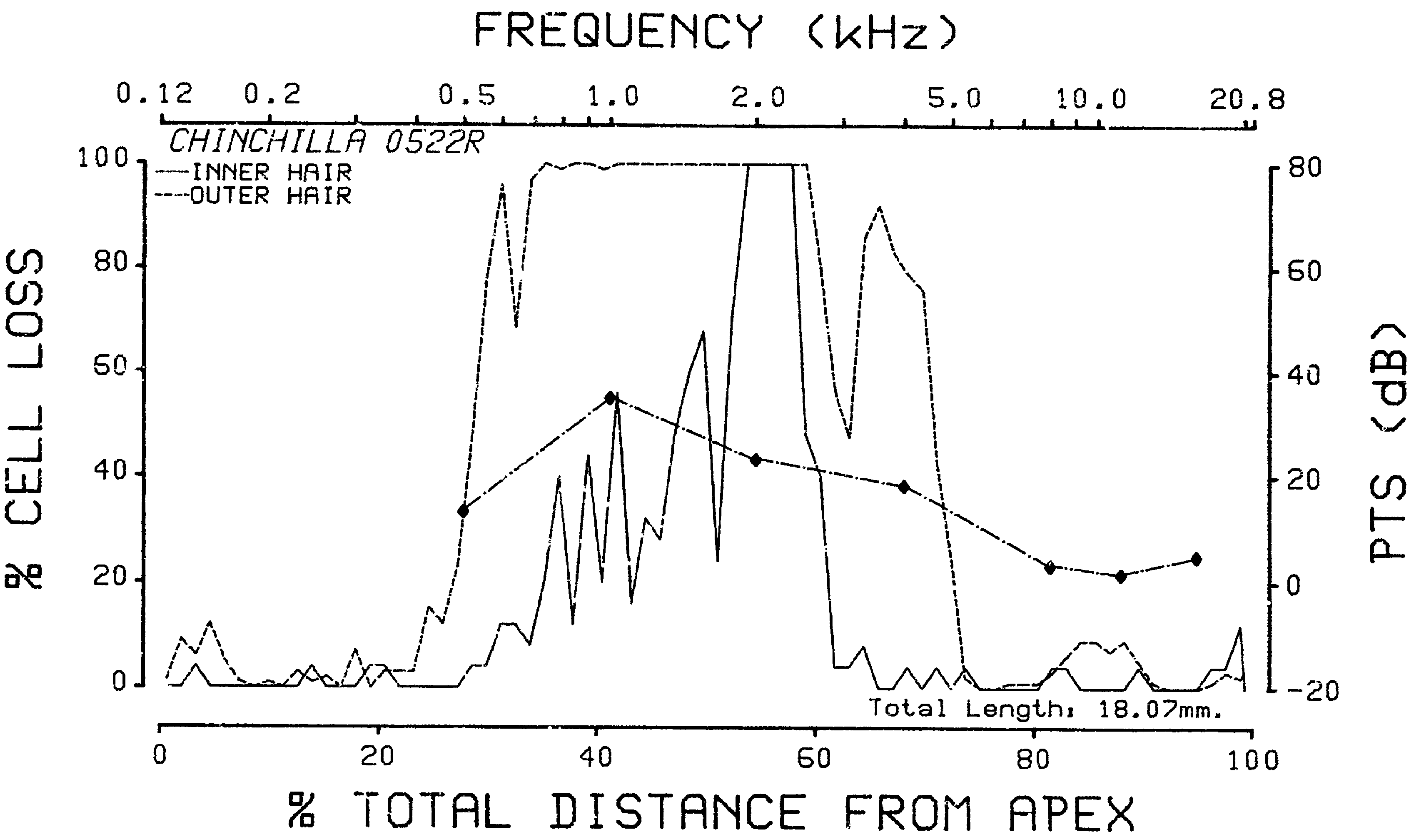

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0515R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 19.18mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

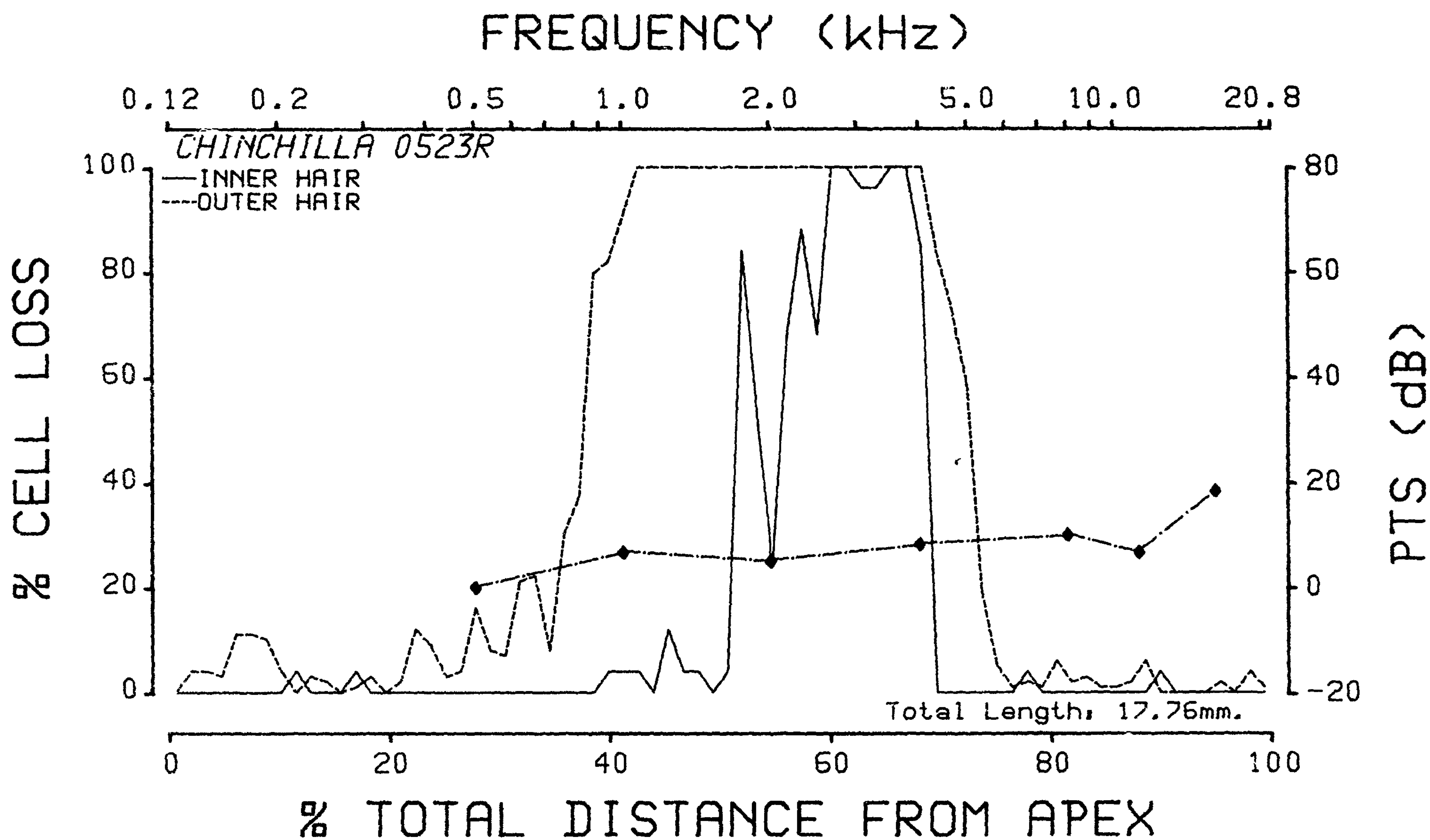

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0517R
INNER HAIR
OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.03mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

167



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0518R
--INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
50
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 19.01mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0522R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.07mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0523R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.76mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

Summary Data for the Group Exposed to:

160 dB, 10X, 1/10M

Animal #		
0445	-	Completed the Entire Protocol
0492	-	Completed the Entire Protocol
0503	-	Completed the Entire Protocol
0506	-	Completed the Entire Protocol
0508	-	Completed the Entire Protocol

160 dB 10X 1/10M

PRE-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0445	20.8	10.8	15.8	-0.8	15.8	19.2	22.5
0492	20.8	7.5	9.2	5.8	15.8	17.5	32.5
0503	30.8	17.5	19.2	9.2	22.5	15.8	42.5
0506	29.2	12.5	15.8	5.8	15.8	14.2	17.5
0508	22.5	9.2	14.2	7.5	17.5	25.8	25.8
Mean	24.8	11.5	14.8	5.5	17.5	18.5	28.2
S.D.	4.8	3.8	3.7	3.8	2.9	4.5	9.7

POST-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0445	24.2	22.5	25.8	2.5	19.2	20.8	15.8
0492	15.8	5.8	20.8	2.5	12.5	14.2	27.5
0503	27.5	15.8	25.8	7.5	19.2	10.8	29.2
0506	37.5	37.5	45.8	19.2	15.8	14.2	12.5
0508	19.2	9.2	14.2	7.5	14.2	24.2	24.2
Mean	24.8	18.2	26.5	7.8	16.2	16.8	21.8
S.D.	8.4	12.6	11.8	6.8	3.0	5.5	7.3

PERMANENT THRESHOLD SHIFT (dB)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0445	3.3	11.7	10.0	3.3	3.3	1.7	-6.7
0492	-5.0	-1.7	11.7	-3.3	-3.3	-3.3	-5.0
0503	-3.3	-1.7	6.7	-1.7	-3.3	-5.0	-13.3
0506	8.3	25.0	30.0	13.3	0.0	0.0	-5.0
0508	-3.3	0.0	0.0	0.0	-3.3	-1.7	-1.7
Mean	0.0	6.7	11.7	2.3	-1.3	-1.7	-6.3
S.D.	5.7	11.7	11.2	6.6	3.0	2.6	4.3

160 dB 10X 1/10M

TEMPORARY THRESHOLD SHIFT (dB)

Frequency 0.5 kHz

Animal\Hr	0	2	8	24	240	Max
0445	16.7	1.7	6.7	1.7	6.7	16.7
0492	6.7	1.7	*****	-3.3	-3.3	6.7
0503	51.7	51.7	31.7	36.7	-3.3	51.7
0506	43.3	43.3	33.3	28.3	13.3	43.3
0508	20.0	0.0	0.0	0.0	0.0	20.0
Mean	27.7	19.7	17.9	12.7	2.7	27.7
S.D.	19.0	25.6	17.1	18.4	7.2	19.0

Frequency 2.0 kHz

Animal\Hr	0	2	8	24	240	Max
0445	31.7	16.7	11.7	6.7	1.7	31.7
0492	48.3	28.3	*****	13.3	3.3	48.3
0503	63.3	63.3	43.3	28.3	3.3	63.3
0506	72.2*	72.2*	56.7	46.7	31.7	72.2
0508	38.3	8.3	3.3	3.3	3.3	38.3
Mean	50.8	37.8	28.8	19.7	8.7	50.8
S.D.	16.9	28.5	25.4	17.9	12.9	16.9

Frequency 8.0 kHz

Animal\Hr	0	2	8	24	240	Max
0445	56.7	36.7	31.7	21.7	16.7	56.7
0492	51.7	16.7	*****	6.7	-8.3	51.7
0503	60.0	60.0	10.0	10.0	10.0	60.0
0506	76.7	76.7	66.7	41.7	1.7	76.7
0508	50.0	20.0	20.0	5.0	0.0	50.0
Mean	59.0	42.0	32.1	17.0	4.0	59.0
S.D.	10.6	25.9	24.7	15.3	9.6	10.6

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 1/10M

Probe Frequency: 0.5 kHz

Masker (kHz):		0.150	0.200	0.300	0.400	0.520	0.600	0.650	0.750	1.300	2.200
Animal	(Q-10 dB)					Pre-Exposure					
0445	(1.74)	72.5	52.5	47.5	37.5	27.5	32.5	32.5	42.5	62.5	82.5
0492	(1.55)	77.5	77.5	57.5	42.5	37.5	42.5	42.5	52.5	57.5	82.5
0503	(1.72)	77.5	67.5	57.5	47.5	42.5	47.5	52.5	57.5	72.5	92.5
0506	(3.11)	67.5	62.5	57.5	47.5	37.5	32.5	42.5	42.5	72.5	95.0*
0508	(2.06)	82.5	72.5	62.5	52.5	47.5	57.5	57.5	72.5	82.5	95.0*
Mean	(2.04)	75.5	66.5	56.5	45.5	38.5	42.5	45.5	53.5	69.5	89.5
S.D.	(0.63)	5.7	6.5	5.5	5.7	7.4	10.6	9.7	12.4	9.7	6.5
Animal	(Q-10 dB)					Post-Exposure					
0445	(2.61)	67.5	62.5	52.5	42.5	32.5	42.5	37.5	42.5	57.5	77.5
0492	(1.12)	77.5	62.5	57.5	42.5	37.5	42.5	37.5	37.5	92.5	95.0*
0503	(1.57)	62.5	72.5	52.5	47.5	47.5	47.5	42.5	57.5	67.5	95.0*
0506	(0.58)	57.5	62.5	52.5	52.5	52.5	52.5	52.5	67.5	105.0*	95.0*
0508	(1.09)	67.5	72.5	57 5	47.5	42.5	42.5	42.5	47.5	77.5	95.0*
Mean	(1.39)	66.5	66.5	54.5	46.5	42.5	45.5	42.5	50.5	80.0	91.5
S.D.	(0.77)	7.4	5.5	2.7	4.2	7.9	4.5	6.1	12.0	19.0	7.8

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 1/10M

Probe Frequency: 1.0 kHz

Masker (kHz):		0.150	0.200	0.400	0.550	0.800	1.050	1.300	1.700	1.900	2.500
Animal	(Q-10 dB)					Pre-Exposure					
0445	(1.72)	77.5	62.5	47.5	42.5	37.5	22.5	27.5	37.5	57.5	62.5
0492	(1.53)	82.5	87.5	67.5	52.5	42.5	32.5	37.5	47.5	52.5	72.5
0503	(1.17)	77.5	77.5	67.5	57.5	47.5	37.5	37.5	47.5	67.5	87.5
0506	(1.92)	82.5	72.5	62.5	57.5	42.5	27.5	32.5	47.5	57.5	87.5
0508	(2.10)	77.5	72.5	67.5	62.5	37.5	27.5	37.5	62.5	77.5	91.0*
Mean	(1.69)	79.5	74.5	62.5	54.5	41.5	29.5	34.5	48.5	62.5	80.2
S.D.	(0.36)	2.7	9.1	8.7	7.6	4.2	5.7	4.5	8.9	10.0	12.2
Animal	(Q-10 dB)					Post-Exposure					
0445	(2.18)	77.5	72.5	72.5	62.5	57.5	42.5	37.5	52.5	62.5	82.5
0492	(4.17)	87.5	92.5	67.5	57.5	47.5	27.5	47.5	77.5	92.5	91.0*
0503	(1.26)	77.5	67.5	62.5	57.5	37.5	37.5	47.5	62.5	57.5	72.5
0506	(2.55)	67.5	67.5	72.5	67.5	62.5	52.5	67.5	72.5	100.0*	91.0*
0508	(3.90)	72.5	72.5	62.5	57.5	47.5	22.5	37.5	52.5	57.5	91.0*
Mean	(2.81)	76.5	74.5	67.5	60.5	50.5	36.5	47.5	63.5	74.0	85.6
S.D.	(1.22)	7.4	10.4	5.0	4.5	9.7	11.9	12.2	11.4	20.6	8.2

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 1/10M

Probe Frequency: 2.0 kHz

Masker (kHz):		0.300	0.750	0.900	1.300	1.700	2.050	2.200	3.000	3.500	4.000
Animal	(Q-10 dB)	Pre-Exposure									
0445	(4.09)	72.5	57.5	52.5	47.5	32.5	22.5	32.5	37.5	47.5	62.5
0492	(4.01)	72.5	52.5	42.5	37.5	42.5	22.5	27.5	47.5	57.5	90.0*
0503	(2.77)	82.5	57.5	52.5	42.5	37.5	27.5	32.5	47.5	67.5	92.5
0506	(2.29)	82.5	57.5	52.5	47.5	47.5	32.5	32.5	47.5	77.5	96.0*
0508	(1.48)	72.5	57.5	47.5	37.5	37.5	37.5	32.5	52.5	62.5	87.5
Mean	(2.93)	76.5	56.5	49.5	42.5	39.5	28.5	31.5	46.5	62.5	85.7
S.D.	(1.13)	5.5	2.2	4.5	5.0	5.7	6.5	2.2	5.5	11.2	13.3
Animal	(Q-10 dB)	Post-Exposure									
0445	(3.61)	82.5	67.5	52.5	47.5	52.5	37.5	42.5	62.5	72.5	87.5
0492	(3.33)	82.5	57.5	47.5	42.5	47.5	37.5	42.5	72.5	87.0*	96.0*
0503	(3.61)	82.5	72.5	67.5	57.5	52.5	37.5	42.5	62.5	77.5	85.0*
0506	(*****)	92.5	62.5	62.5	72.5	77.5	67.5	72.5	62.5	57.5	52.5
0508	(1.80)	67.5	52.5	47.5	42.5	37.5	32.5	37.5	52.5	72.5	87.5
Mean	(3.09)	81.5	62.5	55.5	52.5	53.5	42.5	47.5	62.5	73.4	81.7
S.D.	(0.87)	8.9	7.9	9.1	12.7	14.7	14.1	14.1	7.1	10.7	16.8

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 1/10M

Probe Frequency: 4.0 kHz

Masker (kHz):		0.450	1.300	2.200	3.000	3.500	4.100	4.500	5.000	5.600	6.000
Animal	(Q-10 dB)					Pre-Exposure					
0445	(6.09)	72.5	57.5	52.5	52.5	27.5	12.5	27.5	27.5	52.5	67.5
0492	(5.06)	82.5	62.5	67.5	57.5	37.5	22.5	32.5	42.5	77.5	94.0*
0503	(2.21)	87.5	62.5	47.5	42.5	27.5	27.5	32.5	42.5	77.5	87.5
0506	(4.29)	77.5	57.5	52.5	52.5	42.5	22.5	27.5	37.5	52.5	62.5
0508	(4.22)	87.5	67.5	57.5	52.5	47.5	32.5	37.5	52.5	72.5	92.0*
Mean	(4.38)	81.5	61.5	55.5	51.5	36.5	23.5	31.5	40.5	66.5	80.7
S.D.	(1.43)	6.5	4.2	7.6	5.5	8.9	7.4	4.2	9.1	12.9	14.6
Animal	(Q-10 dB)					Post-Exposure					
0445	(3.30)	82.5	52.5	57.5	52.5	32.5	22.5	27.5	37.5	57.5	67.5
0492	(3.14)	82.5	62.5	62.5	57.5	32.5	32.5	27.5	42.5	72.5	82.5
0503	(4.10)	72.5	57.5	47.5	37.5	32.5	22.5	32.5	37.5	67.5	67.5
0506	(2.11)	77.5	57.5	52.5	57.5	47.5	27.5	27.5	32.5	32.5	47.5
0508	(2.62)	72.5	52.5	52.5	52.5	22.5	22.5	27.5	42.5	62.5	105.0*
Mean	(3.05)	77.5	56.5	54.5	51.5	33.5	25.5	28.5	38.5	58.5	74.0
S.D.	(0.75)	5.0	4.2	5.7	8.2	8.9	4.5	2.2	4.2	15.6	21.3

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 1/10M

Probe Frequency: 8.0 kHz

Masker (kHz):		0.450	1.300	2.500	5.900	7.000	8 100	9.300	11.000	12.700	14.000
Animal	(Q-10 dB)					Pre-Exposure					
0445	(3.78)	82.5	67.5	67.5	52.5	37.5	47.5	52.5	62.5	87.5	92.5
0492	(3.01)	82.5	72.5	67.5	52.5	37.5	32.5	42.5	52.5	82.5	87.5
0503	(5.98)	77.5	67.5	62.5	42.5	37.5	37.5	27.5	72.5	100.0*	92.5
0506	(2.38)	82.5	67.5	57.5	47.5	42.5	37.5	47.5	72.5	100.0*	95.0*
0508	(6.09)	92.5	82.5	72.5	47.5	52.5	37.5	57.5	92.5	100.0*	95.0*
Mean	(4.25)	83.5	71.5	65.5	48.5	41.5	38.5	45.3	70.5	94.0	92.5
S.D.	(1.71)	5.5	6.5	5.7	4.2	6.5	5.5	11.5	14.8	8.4	3.1
Animal	(Q-10 dB)					Post-Exposure					
0445	(4.31)	87.5	67.5	62.5	42.5	42.5	32.5	47.5	77.5	92.5	92.5
0492	(2.69)	77.5	67.5	67.5	52.5	37.5	32.5	37.5	62.5	92.5	87.5
0503	(5.82)	77.5	57.5	52.5	42.5	37.5	32.5	22.5	62.5	100.0*	92.5
0506	(1.18)	82.5	62.5	57.5	42.5	42.5	37.5	37.5	42.5	67.5	82.5
0508	(5.29)	67.5	57.5	57.5	42.5	42.5	27.5	42.5	57.5	67.5	72.5
Mean	(3.86)	78.5	62.5	59.5	44.5	40.5	32.5	37.5	60.5	84.0	85.5
S.D.	(1.91)	7.4	5.0	5.7	4.5	2.7	3.5	9.4	12.5	15.4	8.4

MASKED THRESHOLDS (dB SPL) Group: 160 dB 10X 1/10M

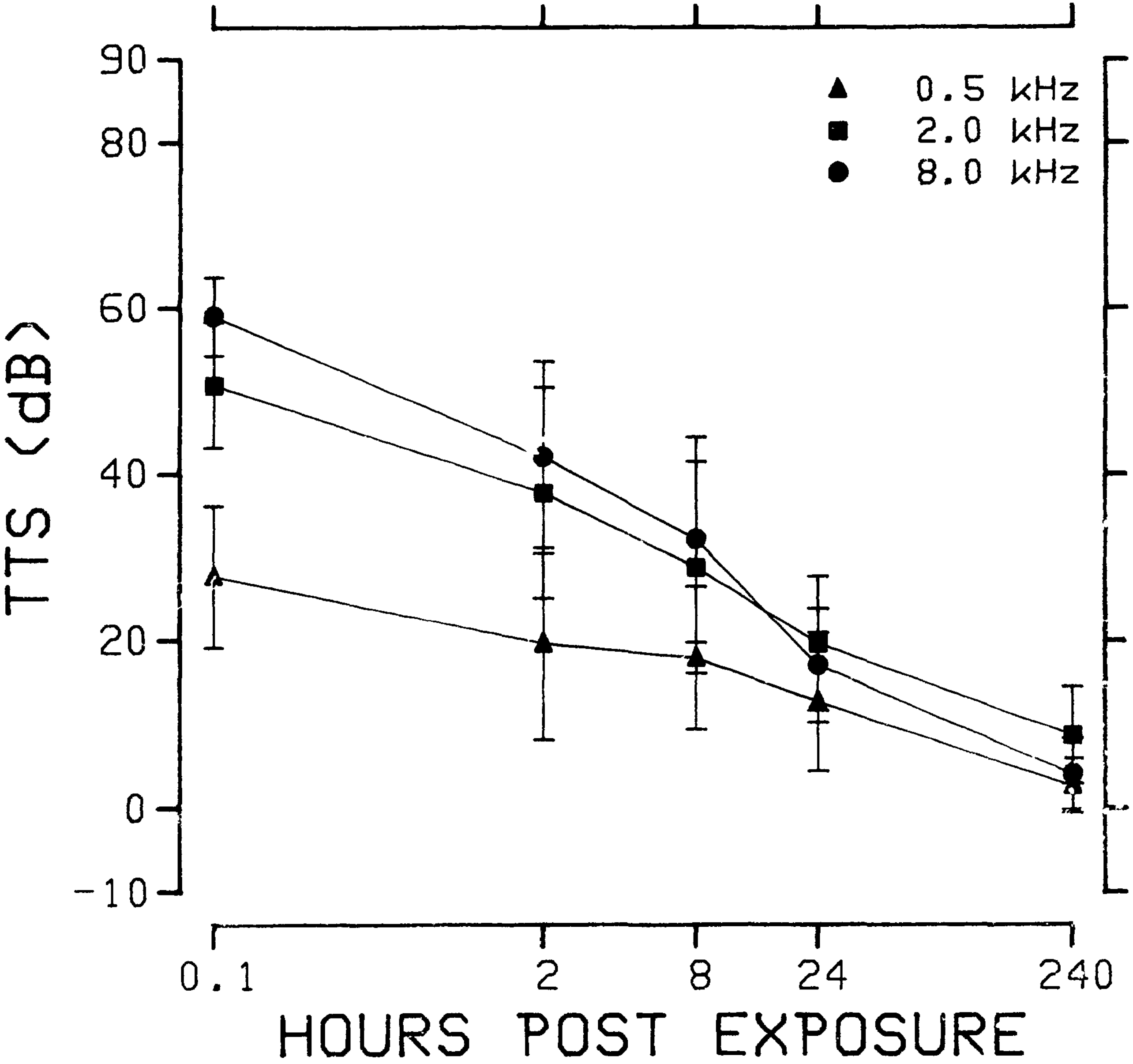
Probe Frequency: 11.2 kHz

Masker (kHz):		1.000	4.000	7.000	9.000	11.000	11.500	12.000	13.000	14.500	16.000
Animal	(Q-10 dB)	Pre-Exposure									
0445	(5.86)	77.5	57.5	52.5	42.5	27.5	37.5	37.5	47.5	52.5	77.5
0492	(3.34)	72.5	62.5	62.5	62.5	42.5	42.5	42.5	47.5	77.5	82.5
0503	(5.18)	62.5	57.5	67.5	47.5	32.5	37.5	47.5	47.5	72.5	91.0*
0506	(5.36)	67.5	52.5	57.5	52.5	32.5	37.5	42.5	37.5	37.5	82.5
0508	(6.57)	82.5	62.5	62.5	62.5	57.5	37.5	37.5	47.5	67.5	91.0*
Mean	(5.26)	72.5	58.5	60.5	53.5	38.5	38.5	41.5	45.5	65.5	84.9
S.D.	(1.20)	7.9	4.2	5.7	8.9	11.9	2.2	4.2	4.5	10.4	5.9
Animal	(Q-10 dB)	Post-Exposure									
0445	(8.15)	67.5	47.5	62.5	57.5	32.5	42.5	42.5	42.5	57.5	77.5
0492	(5.40)	67.5	62.5	67.5	62.5	32.5	32.5	37.5	52.5	82.5	91.0*
0503	(2.57)	62.5	52.5	57.5	42.5	32.5	32.5	32.5	37.5	62.5	102.0*
0506	(5.75)	67.5	52.5	57.5	52.5	37.5	27.5	32.5	37.5	47.5	72.5
0508	(2.91)	67.5	52.5	67.5	57.5	37.5	37.5	42.5	42.5	52.5	95.0*
Mean	(4.96)	66.5	53.5	62.5	54.5	34.5	34.5	37.5	42.5	60.5	87.6
S.D.	(2.29)	2.2	5.5	5.0	7.6	2.7	5.7	5.0	6.1	13.5	12.3

The Group Mean Recovery Curves

Measured at Three Test Frequencies

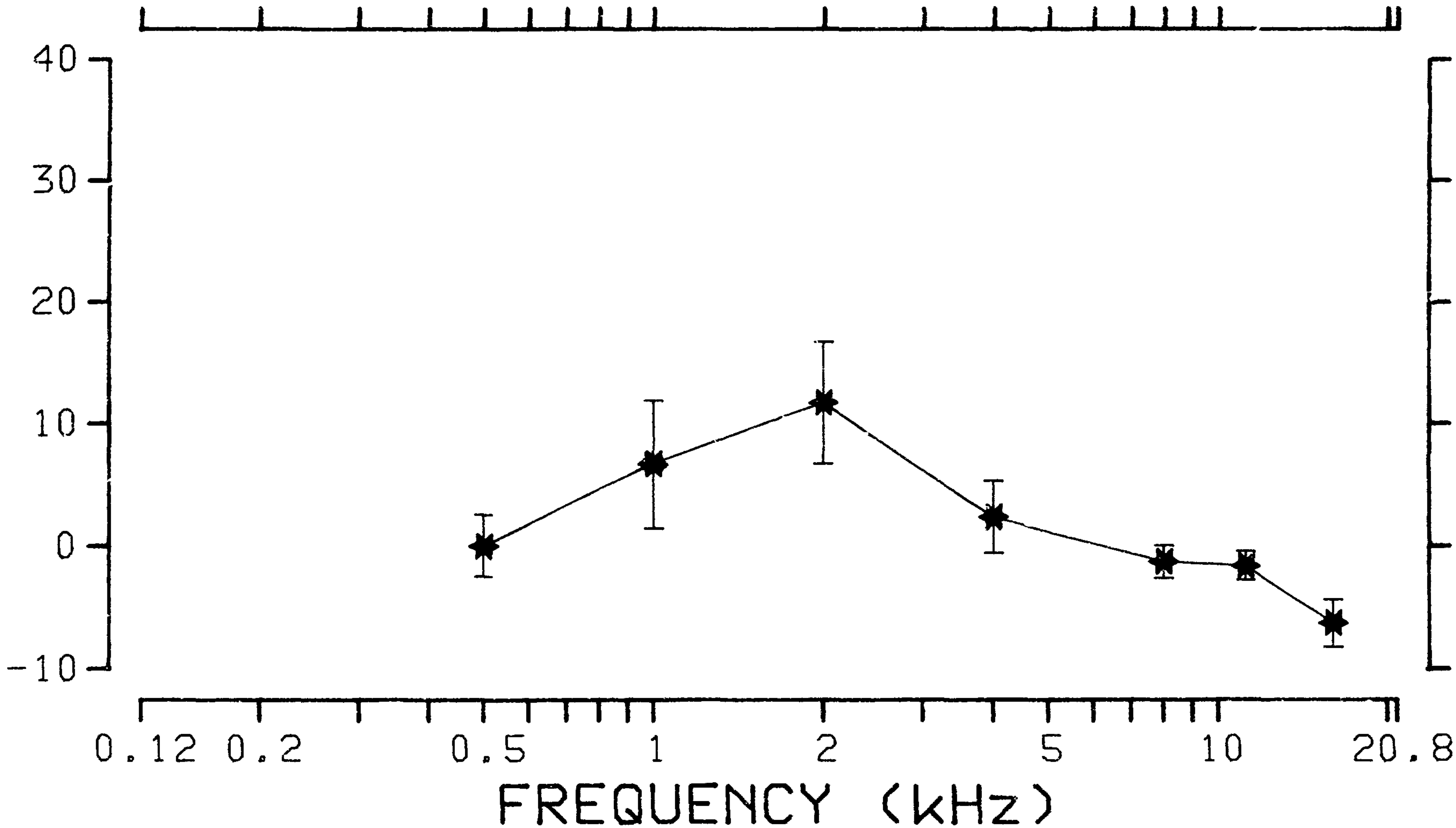
MEAN DATA (n=5) - 160 dB 10X 1/10M



The Group Mean Permanent Threshold Shift (PTS)

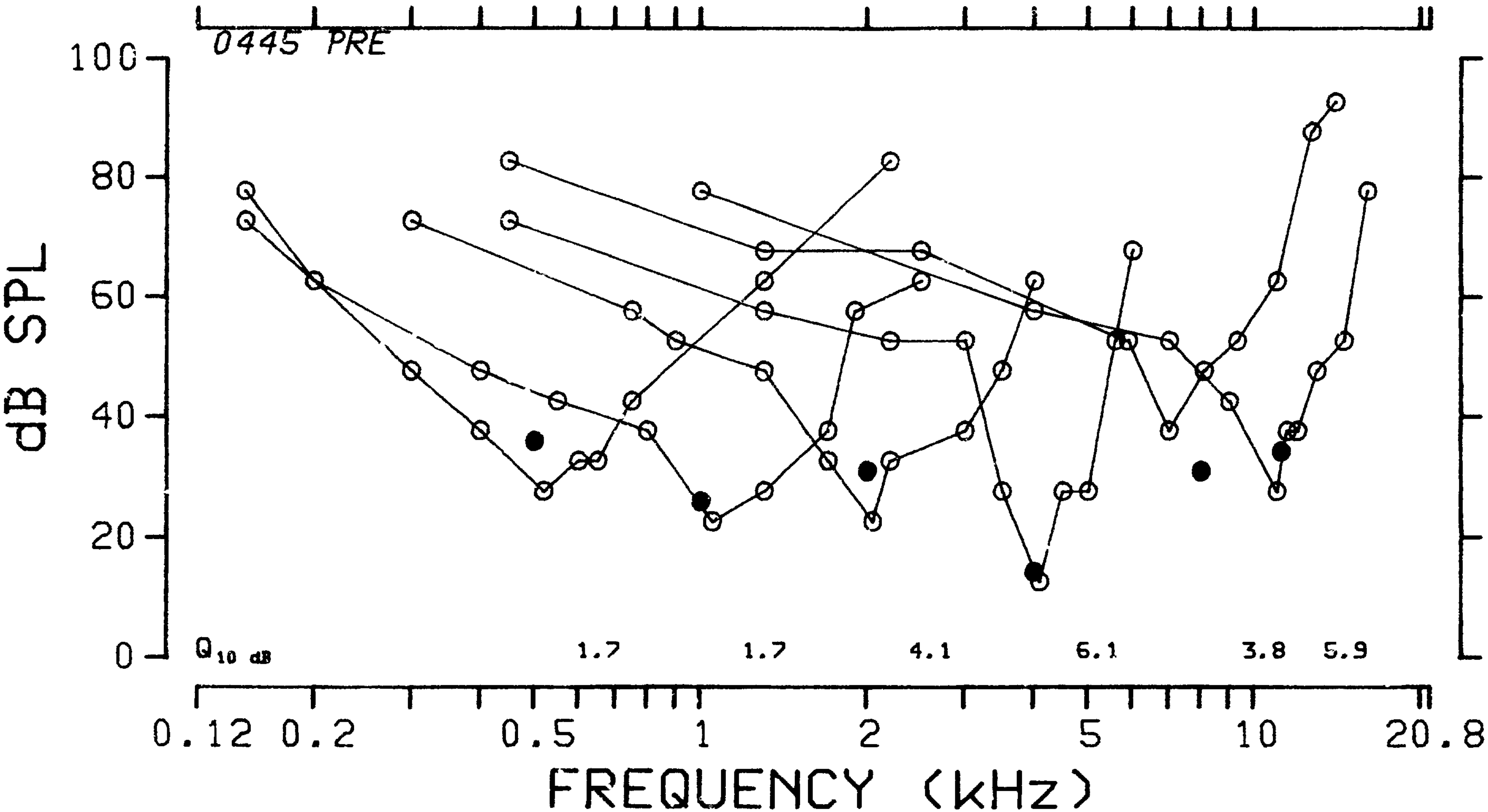
for all Test Frequencies

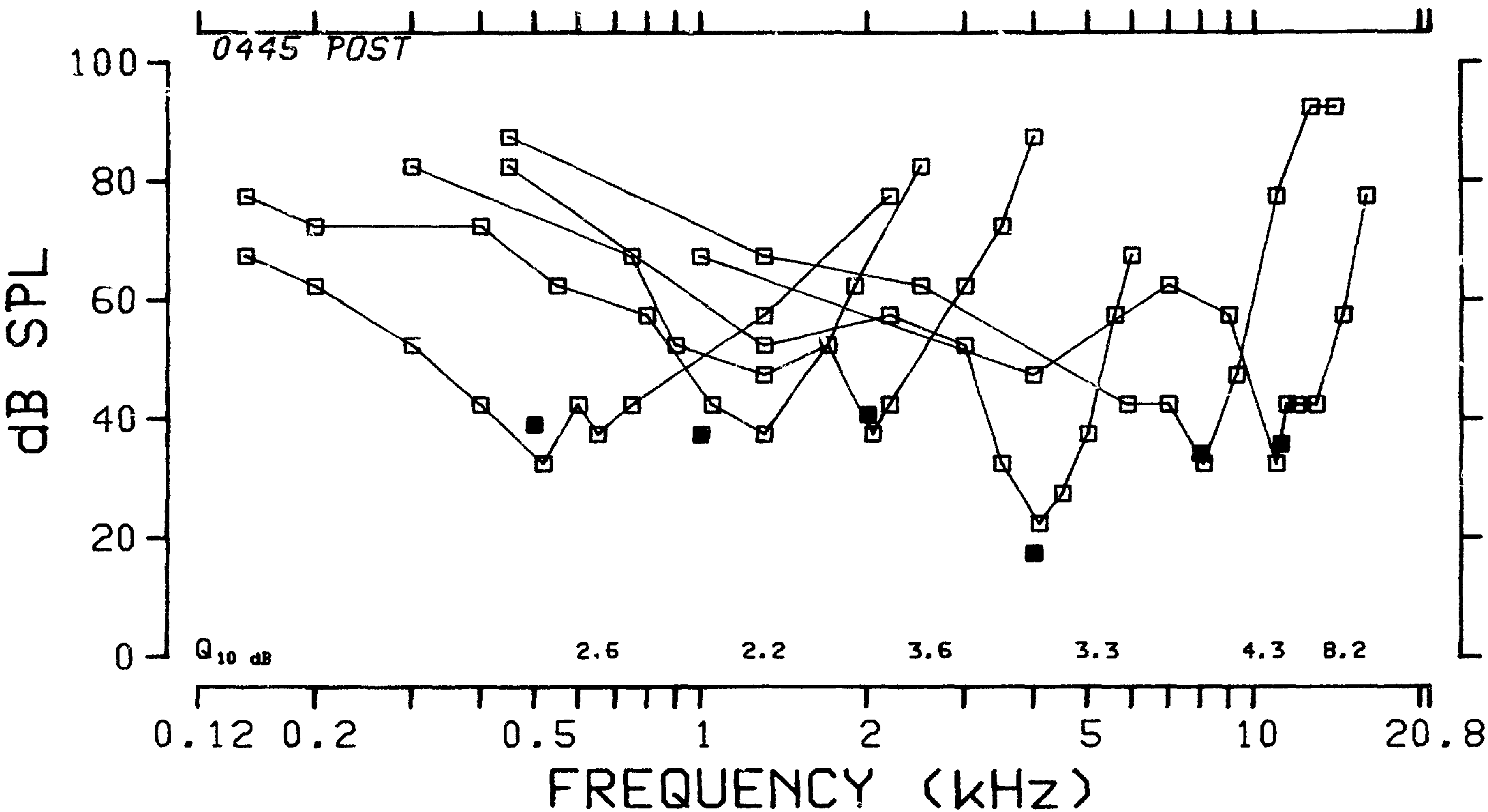
MEAN DATA (n=5) - 160 dB 10X 1/10M

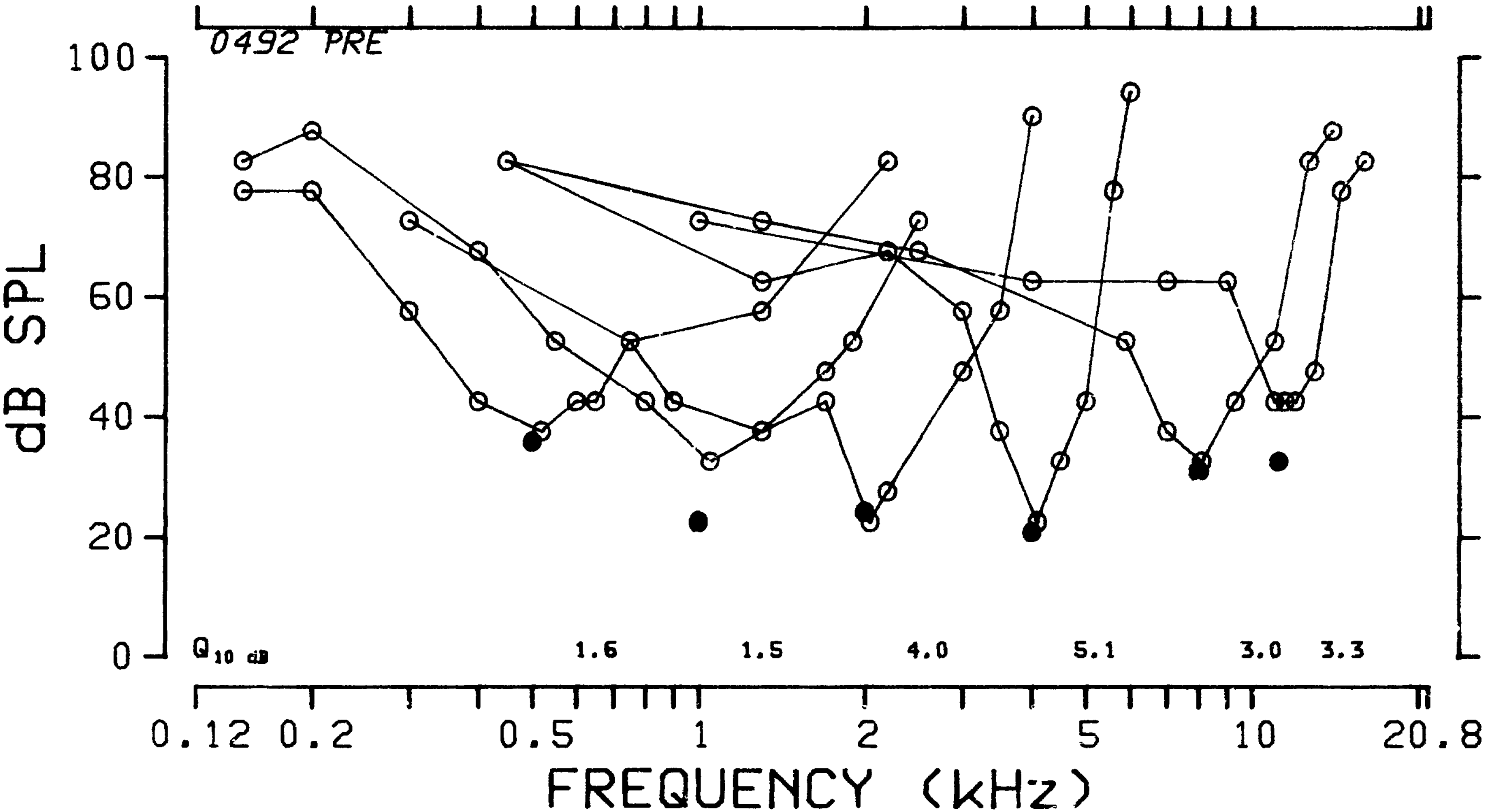


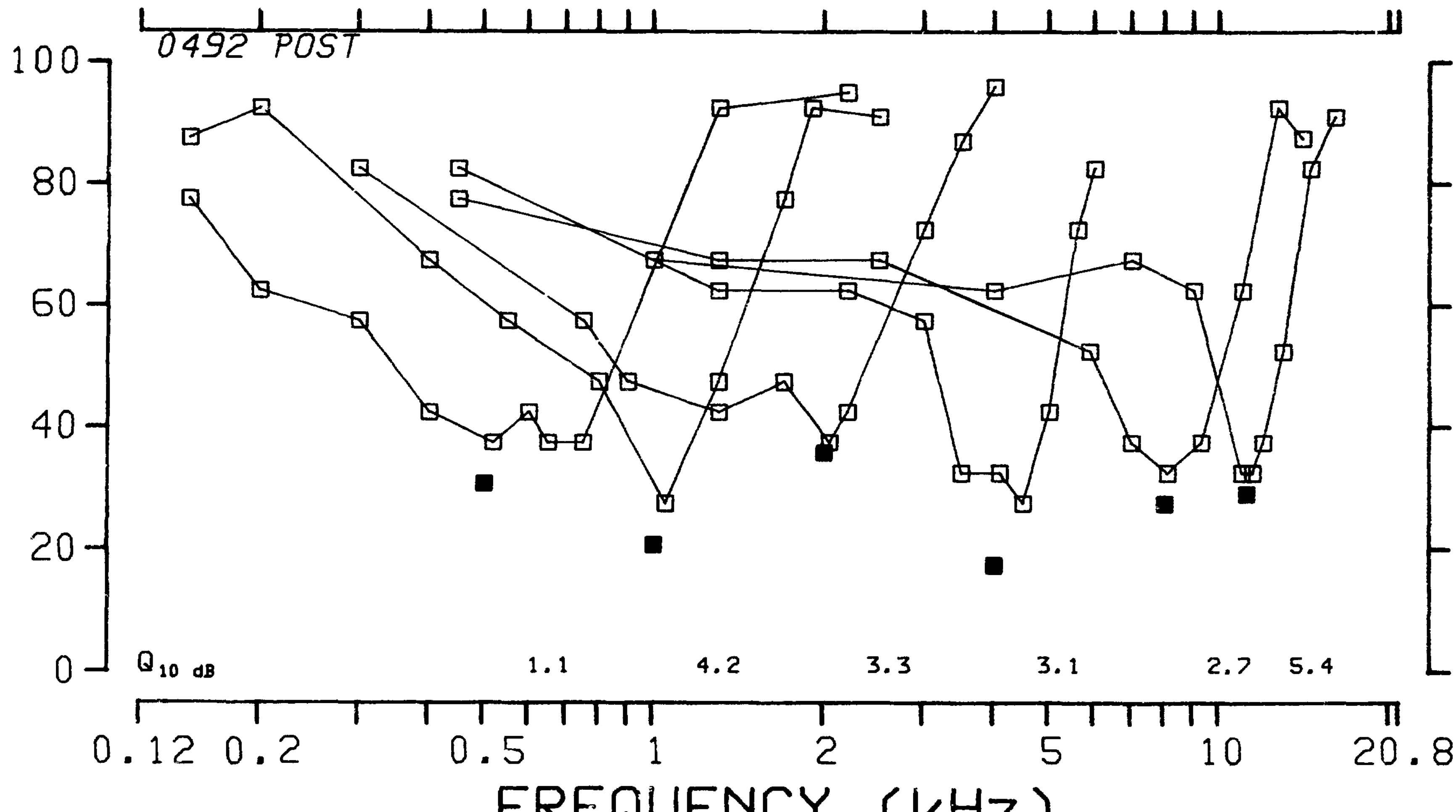
The Pre and Postexposure Tuning Curves for
Individual Animals in this Exposure Group.

The Solid Symbol represents the intensity of the probe tone.

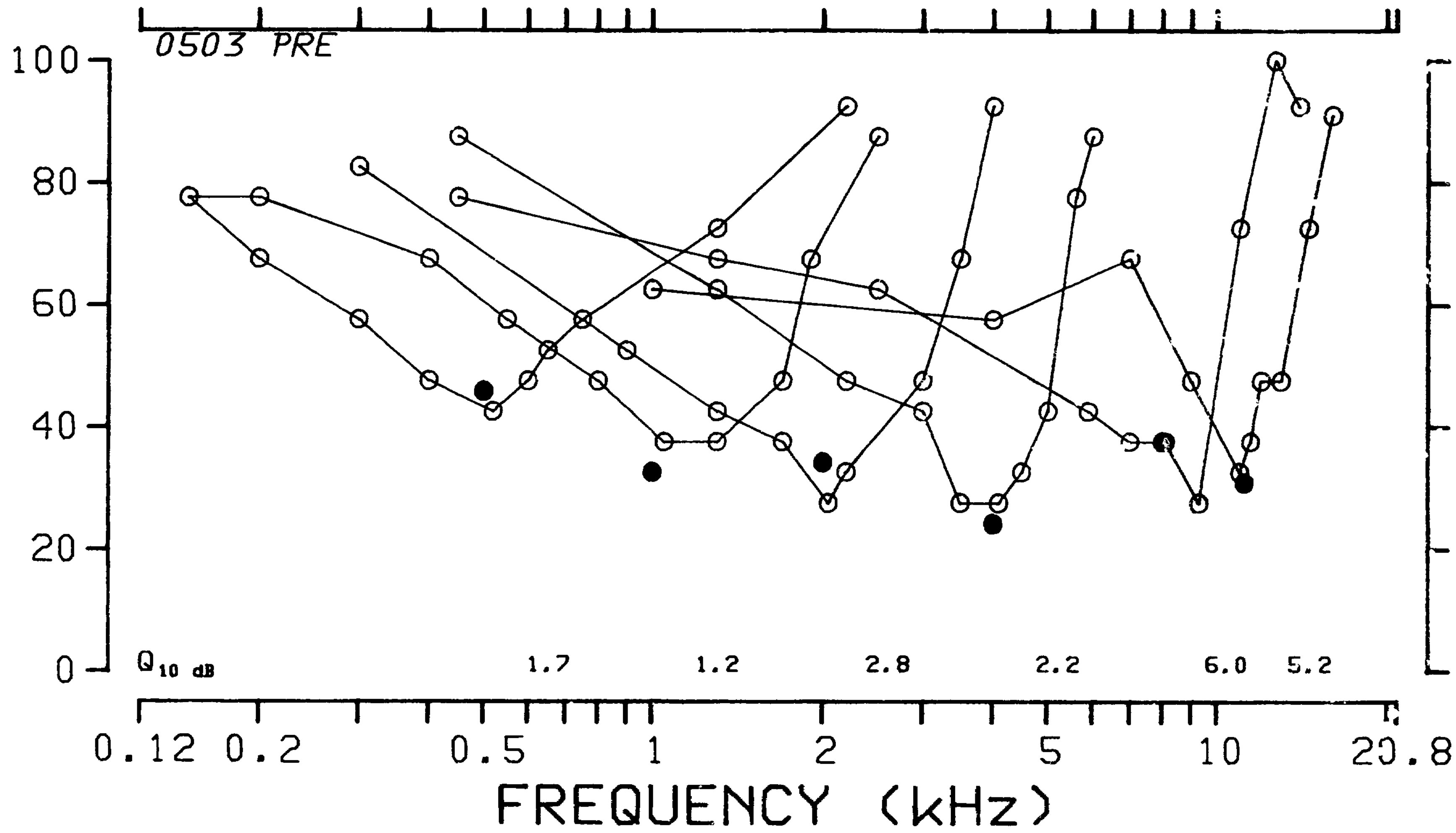

0445 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
1.7
1.7
4.1
6.1
3.8
5.9
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

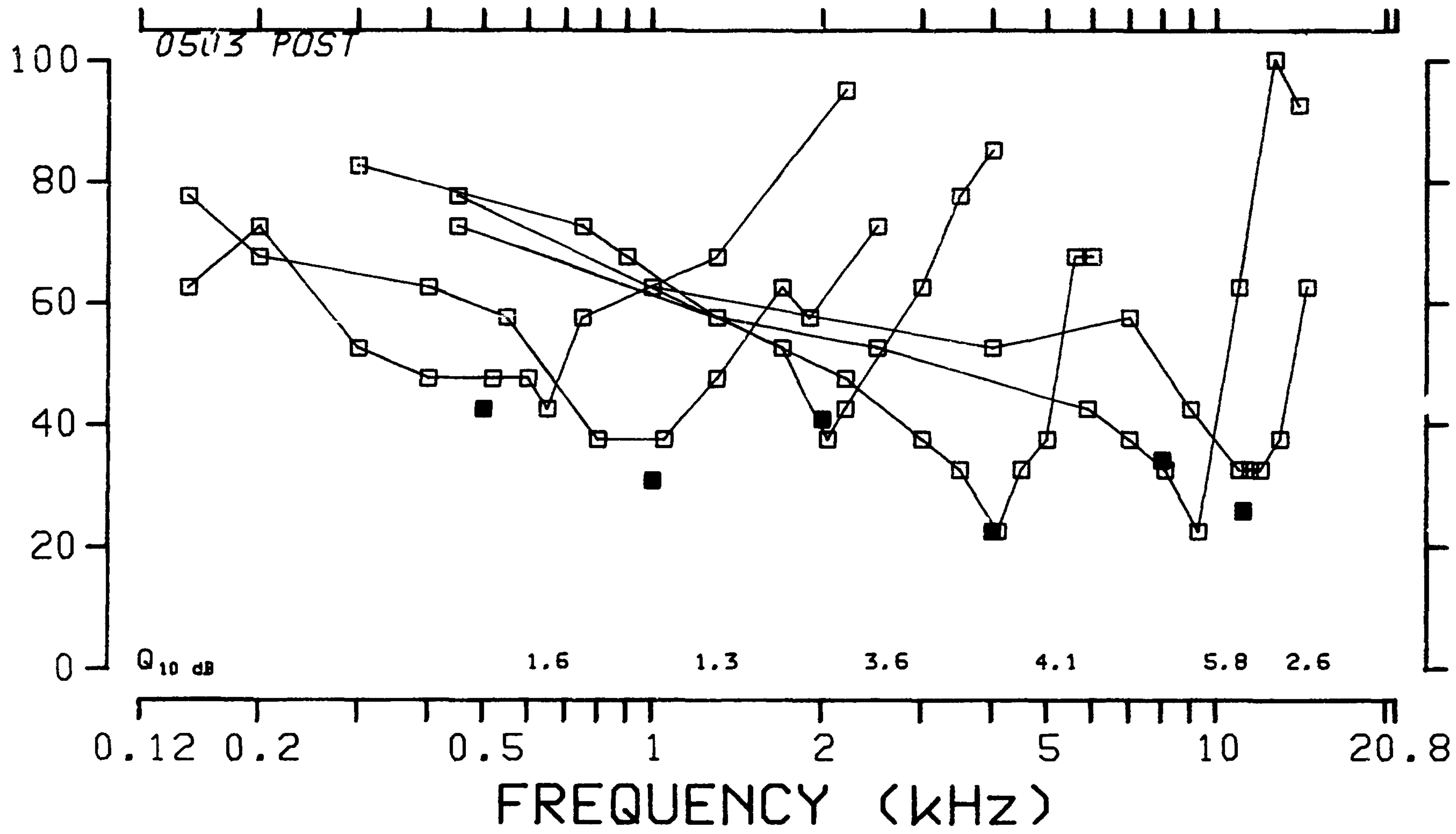

0445 POST
100
80
60
40
20
0
dB SPL
$Q_{10\ dB}$
2.6
2.2
3.6
3.3
4.3
8.2
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0492 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
1.6
1.5
4.0
5.1
3.0
3.3
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

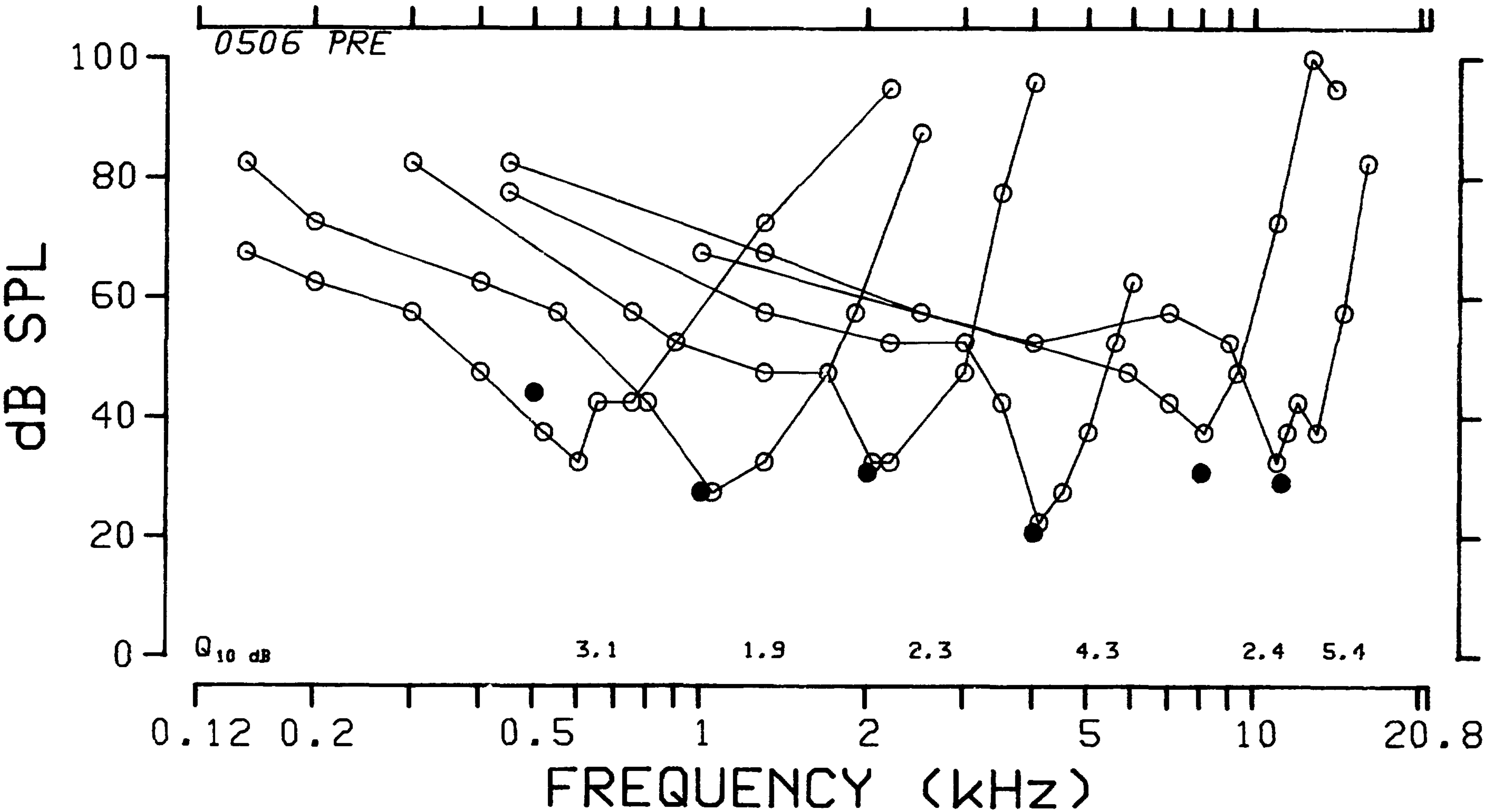

0492 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.1
4.2
3.3
3.1
2.7
5.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

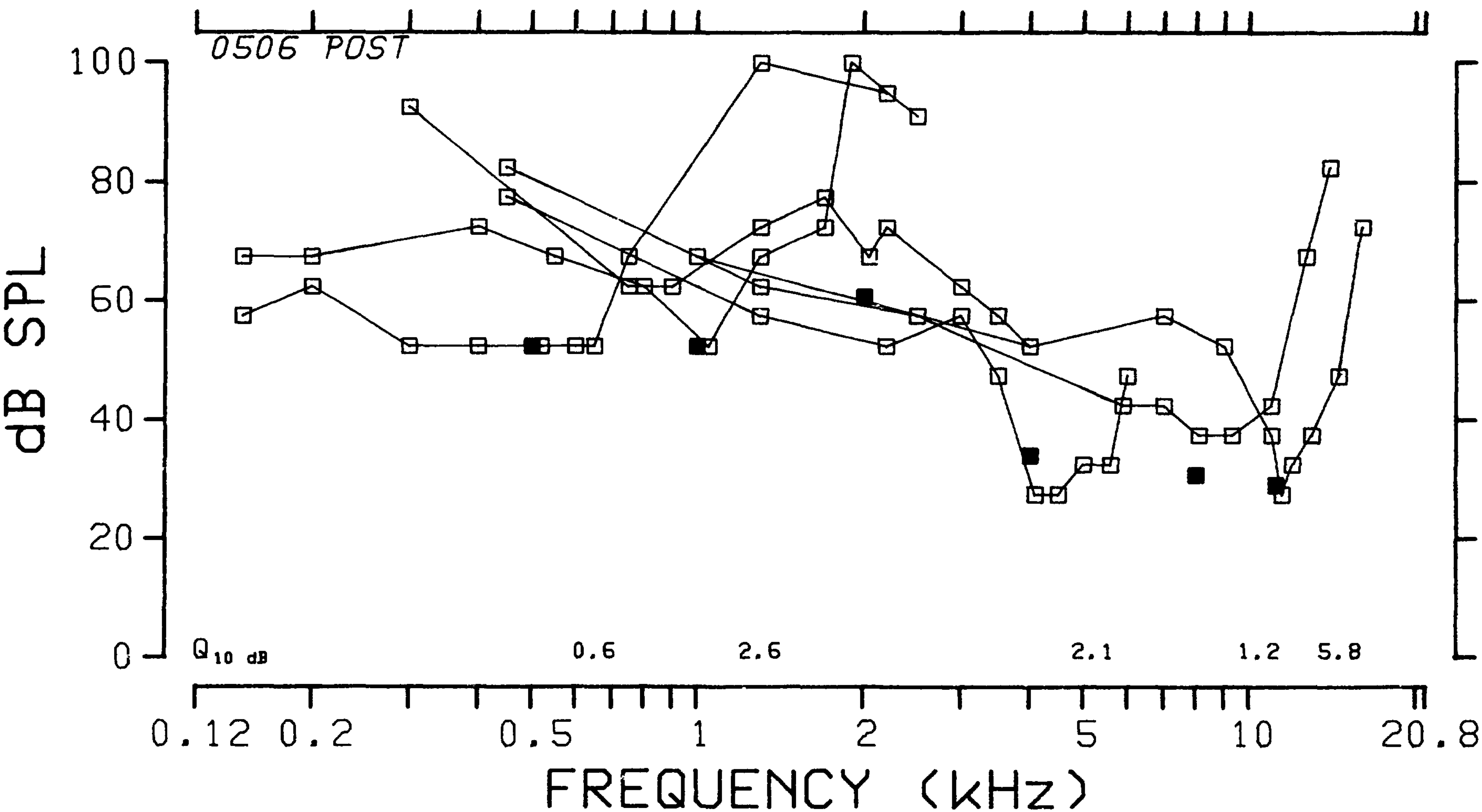
189


0503 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.7
1.2
2.8
2.2
6.0
5.2
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

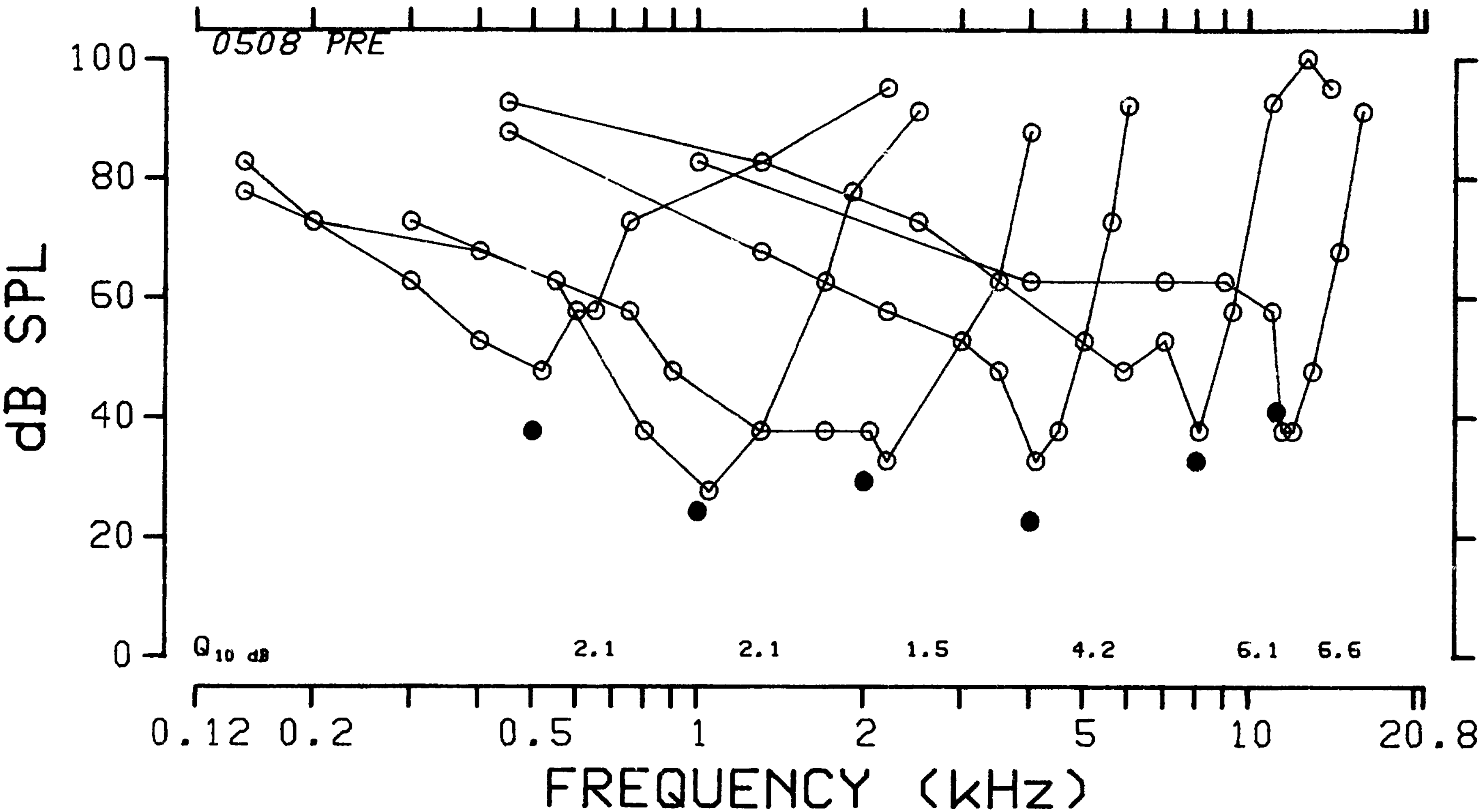

0503 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.6
1.3
3.6
4.1
5.8
2.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

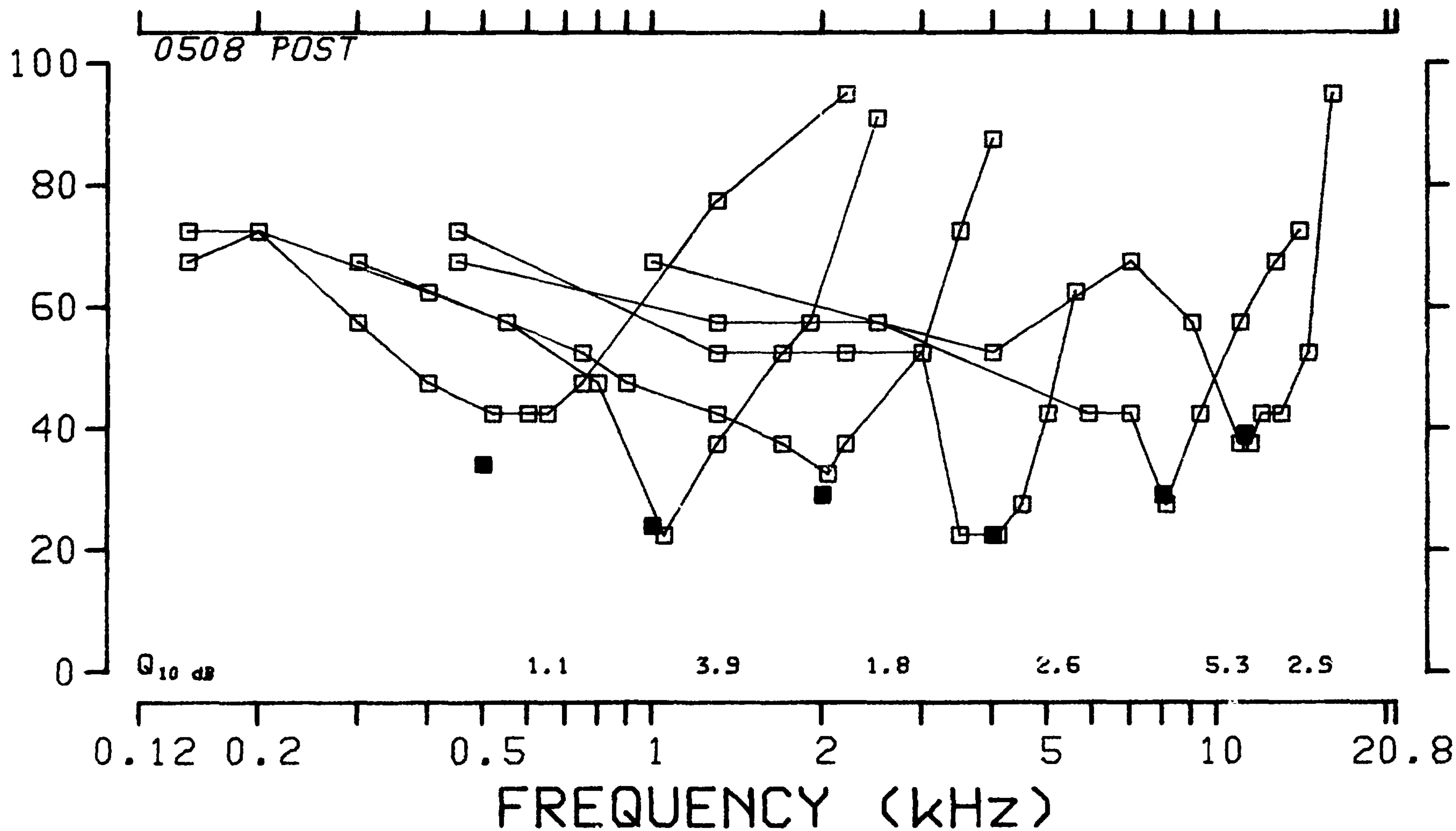
190


0506 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
3.1
1.9
2.3
4.3
2.4
5.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0506 POST
100
80
60
40
20
0
dB SPL
$Q_{10\ dB}$
0.6
2.6
2.1
1.2
5.8
0.12 0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

192


0508 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.1
2.1
1.5
4.2
6.1
6.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0508 POST
100
80
60
40
20
0
dB SPL
$Q_{10\ dB}$
1.1
3.9
1.8
2.6
5.3
2.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

194

160 dB 10X 1/10M

TOTAL NUMBER OF COCHLEAR SENSORY CELLS MISSING

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0445	27	64	64	82	210
0492	5	28	34	58	120
0503	90	247	388	282	917
0506	64	758	816	641	2215
0508	7	24	31	62	117
GROUP MEAN	39				716
S.D.	37				902
S.E.	17				404

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

	OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	OUTER HAIR CELLS
GROUP MEANS			
	0.125 kHz	0.6	33.2
	0.25 kHz	1.0	24.6
	0.5 kHz	0.4	19.2
	1 kHz	5.0	80.0
	2 kHz	2.6	220.2
	4 kHz	10.2	185.4
	8 kHz	8.4	62.4
	16 kHz	10.4	90.8
STANDARD DEVIATIONS			
	0.125 kHz	0.9	7.9
	0.25 kHz	0.7	6.5
	0.5 kHz	0.5	8.2
	1 kHz	7.1	119.1
	2 kHz	4.3	405.0
	4 kHz	20.6	388.4
	8 kHz	15.0	84.2
	16 kHz	22.7	193.0

160 dB 10X 1/10M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0445							
0.125 kHz	0	1	6	18	25	0	0
0.25 kHz	2	2	4	19	25	0	0
0.5 kHz	1	7	10	8	25	0	0
1 kHz	17	7	8	5	20	2	0
2 kHz	0	11	4	6	21	1	0
4 kHz	2	7	2	2	11	1	0
8 kHz	4	25	28	23	76	4	0
16 kHz	1	4	2	1	7	0	0
TOTALS	27	64	64	82	210	8	0
CHINCHILLA 0492							
0.125 kHz	2	2	5	21	28	0	1
0.25 kHz	1	3	3	13	19	0	1
0.5 kHz	0	2	2	4	8	0	0
1 kHz	0	4	5	2	11	1	0
2 kHz	0	3	9	0	12	0	0
4 kHz	2	7	7	9	23	0	0
8 kHz	0	6	3	7	16	0	0
16 kHz	0	1	0	2	3	0	0
TOTALS	5	28	34	58	120	1	2
CHINCHILLA 0503							
0.125 kHz	1	5	14	26	45	0	3
0.25 kHz	1	1	7	19	27	0	0
0.5 kHz	0	3	4	6	13	1	1
1 kHz	2	9	50	8	67	0	0
2 kHz	0	16	98	6	120	0	0
4 kHz	0	0	2	3	5	0	0
8 kHz	35	67	68	69	204	52	36
16 kHz	51	146	145	145	436	113	66
TOTALS	90	247	388	282	917	166	106

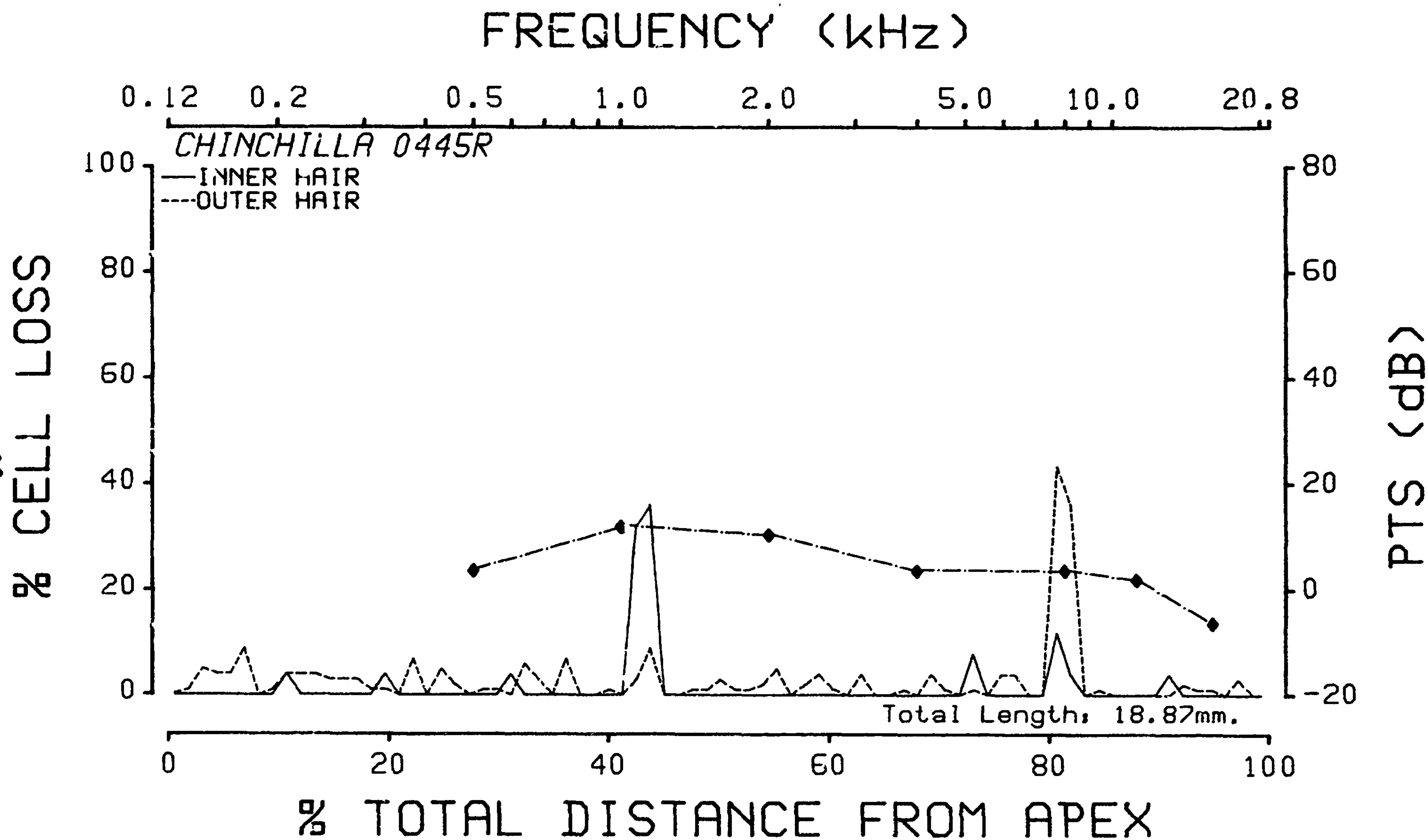
160 dB 10X 1/10M

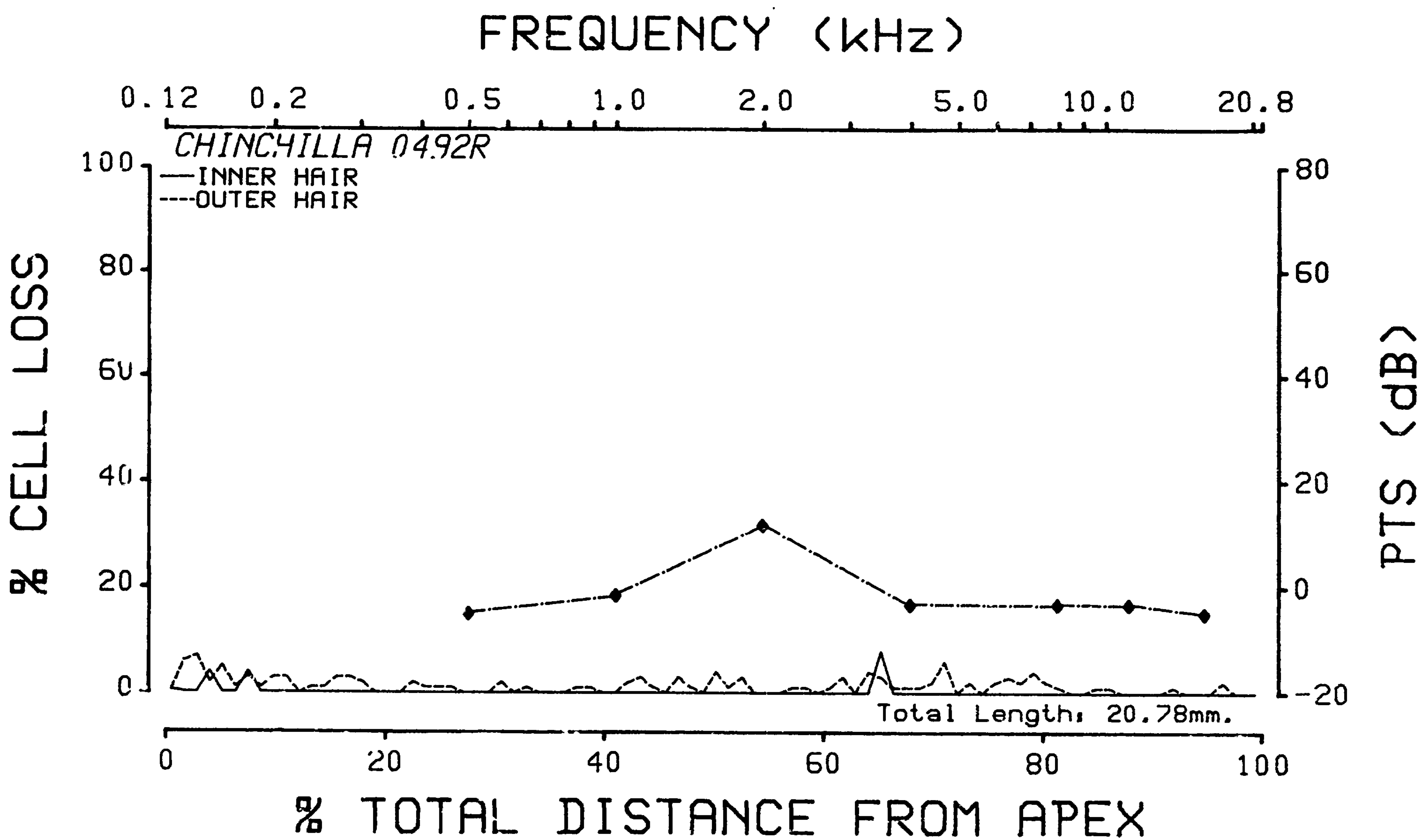
TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0506							
0.125 kHz	0	6	3	22	31	0	11
0.25 kHz	1	8	1	25	34	0	0
0.5 kHz	0	6	19	1	26	0	0
1 kHz	6	99	148	42	289	4	11
2 kHz	10	334	333	273	940	51	103
4 kHz	47	300	303	277	880	120	171
8 kHz	0	5	7	1	13	0	0
16 kHz	0	0	2	0	2	0	0
TOTALS	64	758	816	641	2215	175	296
CHINCHILLA 0508							
0.125 kHz	0	4	8	25	37	0	1
0.25 kHz	0	3	2	13	18	0	0
0.5 kHz	1	6	8	10	24	0	0
1 kHz	0	1	4	8	13	0	0
2 kHz	3	4	2	2	8	0	2
4 kHz	0	3	3	2	8	0	0
8 kHz	3	1	2	0	3	0	0
16 kHz	0	2	2	2	6	0	0
TOTALS	7	24	31	62	117	0	3
GROUP MEANS							
0.125 kHz	0.6	3.6	7.2	22.4	33.2	0.0	3.2
0.25 kHz	1.0	3.4	3.4	17.8	24.6	0.0	0.2
0.5 kHz	0.4	4.8	8.6	5.8	19.2	0.2	0.2
1 kHz	5.0	24.0	43.0	13.0	80.0	1.4	2.2
2 kHz	2.6	73.6	89.2	57.4	220.2	10.4	21.0
4 kHz	10.2	63.4	63.4	58.6	185.4	24.2	34.2
8 kHz	8.4	20.8	21.6	20.0	62.4	11.2	7.2
16 kHz	10.4	30.6	30.2	30.0	90.8	22.6	13.2
TOTALS	38.6	224.2	266.6	225.0	715.8	70.0	81.4

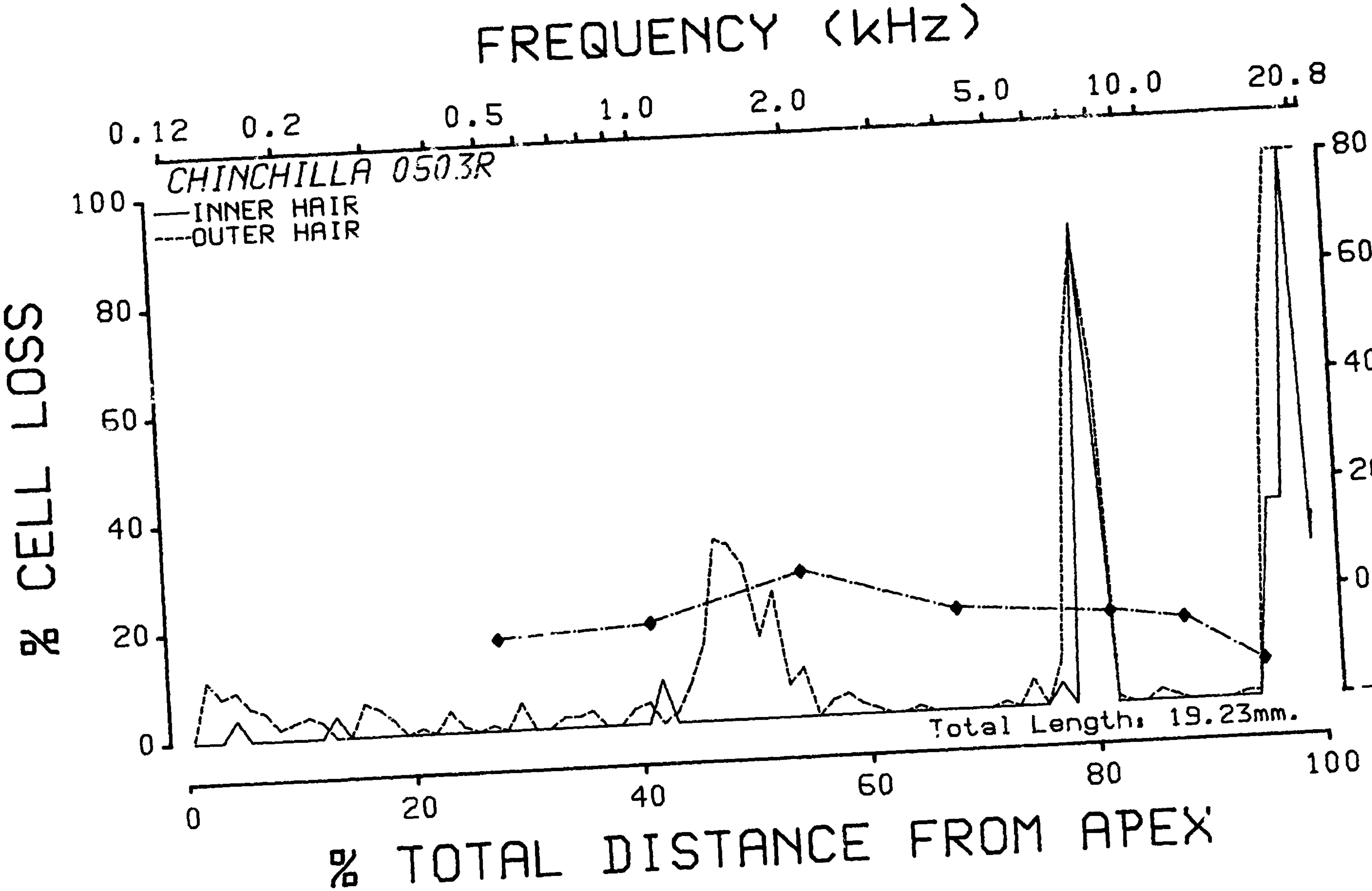
Cochleograms and PTS Audiograms

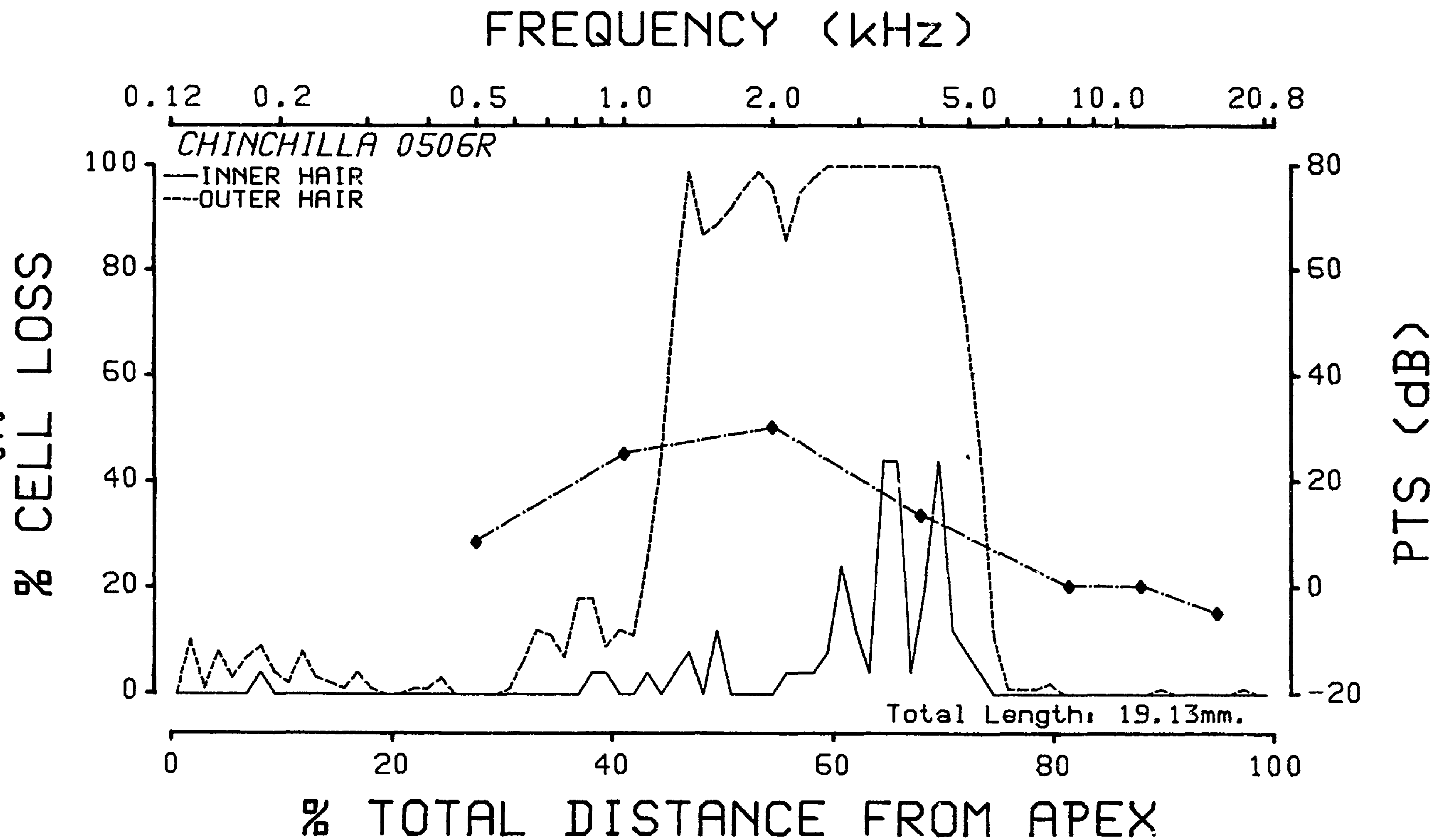
for Individual Animals

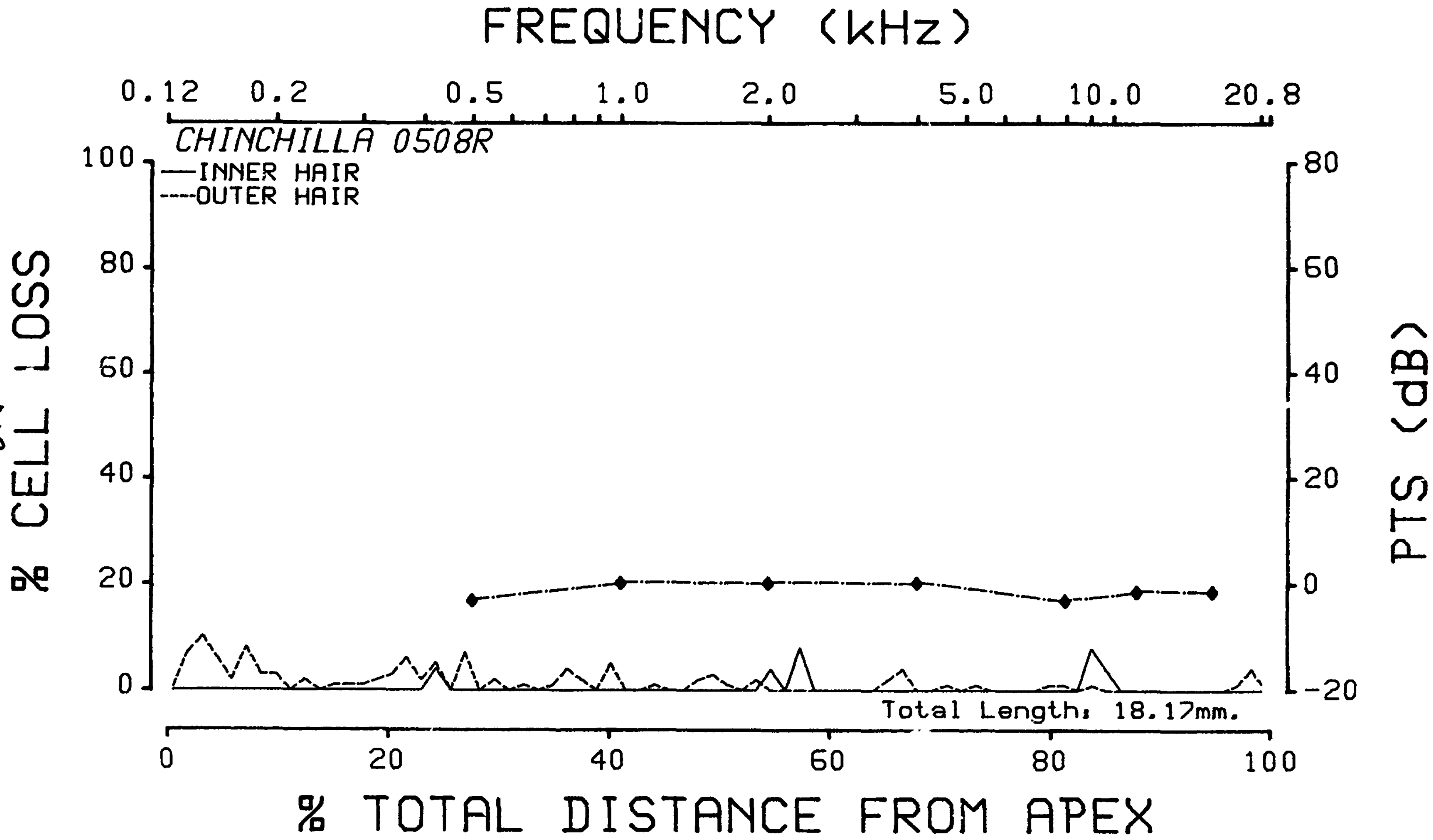

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0445R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.87mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0492R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 20.78mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

200


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0503R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 19.23mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
CHINCHILLA 0506R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100 80 60 40 20 0
PTS (dB)
80 60 40 20 0 -20
Total Length: 19.13mm.
0 20 40 60 80 100
% TOTAL DISTANCE FROM APEX
202


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0508R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.17mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

203

Summary Data for the Group Exposed to:

160 dB, 100X, 10/M

Animal #		
0521	-	Completed the Entire Protocol
0537	-	Completed the Entire Protocol
0542	-	Completed the Entire Protocol
0543	-	Completed the Entire Protocol
0544	-	Completed the Entire Protocol

160 dB 100X 10/M

PRE-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0521	22.5	10.8	19.2	9.2	19.2	15.8	22.5
0537	17.5	0.8	5.8	4.2	20.8	17.5	19.2
0542	17.5	4.2	7.5	-0.8	25.8	22.5	32.5
0543	20.8	5.8	5.8	-0.8	20.8	12.5	15.8
0544	19.2	2.5	5.8	4.2	9.2	14.2	24.2
Mean	19.5	4.8	8.8	3.2	19.2	16.5	22.8
S.D.	2.2	3.8	5.8	4.2	6.1	3.8	6.3

POST-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0521	47.5	47.5	47.5	44.2	59.2	42.5	70.8
0537	47.5	37.5	54.2	22.5	20.0	27.5	36.3
0542	59.2	52.5	57.5	45.8	70.8	62.5	72.5
0543	35.8	7.5	4.2	2.5	22.5	14.2	10.8
0544	44.2	42.5	49.2	34.2	27.5	12.5	22.5
Mean	46.8	37.5	42.5	29.8	40.0	31.8	42.6
S.D.	8.4	17.7	21.8	17.9	23.4	21.0	28.0

PERMANENT THRESHOLD SHIFT (dB)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0521	25.0	36.7	28.3	35.0	40.0	26.7	48.3
0537	30.0	36.7	48.3	18.3	-0.8	10.0	17.1
0542	41.7	48.3	50.0	46.7	45.0	40.0	40.0
0543	15.0	1.7	-1.7	3.3	1.7	1.7	-5.0
0544	25.0	40.0	43.3	30.0	18.3	-1.7	-1.7
Mean	27.3	32.7	33.7	26.7	20.8	15.3	19.8
S.D.	9.7	18.0	21.5	16.5	21.2	17.6	24.0

160 dB 100X 10/M

TEMPORARY THRESHOLD SHIFT (dB)

Frequency 0.5 kHz

Animal\Hr	0	2	8	24	240	Max
0521	72.5*	55.0	72.5*	70.0	30.0	72.5
0537	55.0	77.5*	77.5*	55.0	30.0	77.5
0542	35.0	40.0	35.0	40.0	45.0	45.0
0543	46.7	41.7	36.7	26.7	11.7	46.7
0544	43.3	48.3	43.3	43.3	28.3	48.3
Mean	50.5	52.5	53.0	47.0	29.0	58.0
S.D.	14.2	15.2	20.4	16.4	11.8	15.7

Frequency 2.0 kHz

Animal\Hr	0	2	8	24	240	Max
0521	68.8*	68.8*	68.8*	68.8*	33.3	68.8
0537	76.7	76.7	89.2*	66.7	41.7	89.2
0542	80.5*	80.5*	80.5*	70.0	50.0	80.5
0543	66.7	41.7	31.7	21.7	1.7	66.7
0544	82.2*	82.2*	82.2*	56.7	41.7	82.2
Mean	75.0	70.0	70.5	56.8	33.7	77.5
S.D.	6.9	16.6	22.9	20.3	18.8	9.5

Frequency 8.0 kHz

Animal\Hr	0	2	8	24	240	Max
0521	76.8*	76.8*	76.8*	76.8*	53.3	76.8
0537	36.7	75.2*	61.7	31.7	-8.3	75.2
0542	66.7	70.2*	70.2*	61.7	46.7	70.2
0543	21.7	6.7	6.7	-3.3	-8.3	21.7
0544	86.8*	86.8*	86.8*	53.3	3.3	86.8
Mean	57.7	63.1	60.4	44.0	17.3	66.1
S.D.	27.5	32.1	31.4	31.1	30.3	25.6

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 10/M

Probe Frequency: 0.5 kHz

Masker (kHz):		0.150	0.200	0.300	0.400	0.520	0.600	0.650	0.750	1.300	2.200
Animal	(Q-10 dB)	Pre-Exposure									
0521	(1.49)	77.5	67.5	62.5	52.5	42.5	42.5	42.5	52.5	77.5	92.5
0537	(2.09)	82.5	72.5	57.5	47.5	37.5	42.5	47.5	57.5	77.5	87.5
0542	(2.14)	62.5	62.5	47.5	42.5	37.5	32.5	37.5	52.5	77.5	95.0*
0543	(2.41)	67.5	62.5	52.5	42.5	37.5	32.5	42.5	47.5	82.5	95.0*
0544	(1.66)	72.5	77.5	57.5	47.5	32.5	37.5	37.5	42.5	62.5	95.0*
Mean	(1.96)	72.5	68.5	55.5	46.5	37.5	37.5	41.5	50.5	75.5	93.0
S.D.	(0.37)	7.9	6.5	5.7	4.2	3.5	5.0	4.2	5.7	7.6	3.3
Animal	(Q-10 dB)	Post-Exposure									
0521	(1.55)	92.5	82.5	82.5	72.5	77.5	87.5	77.5	98.0*	95.0*	95.0*
0537	(1.15)	87.5	82.5	82.5	72.5	72.5	72.5	82.5	98.0*	95.0*	95.0*
0542	(1.18)	104.0*	88.0*	87.5	87.5	82.5	87.5	97.5	98.0*	95.0*	95.0*
0543	(5.36)	77.5	72.5	67.5	67.5	62.5	52.5	67.5	72.5	72.5	92.5
0544	(0.95)	77.5	72.5	67.5	67.5	62.5	62.5	62.5	72.5	62.5	87.5
Mean	(2.04)	87.8	79.6	77.5	73.5	71.5	72.5	77.5	87.8	84.0	93.0
S.D.	(1.87)	11.1	6.9	9.4	8.2	8.9	15.4	13.7	14.0	15.5	3.3

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 10/M

Probe Frequency: 1.0 kHz

Masker (kHz):		0.150	0.200	0.400	0.550	0.800	1.050	1.300	1.700	1.900	2.500
Animal	(Q-10 dB)					Pre-Exposure					
0521	(2.04)	77.5	77.5	62.5	57.5	42.5	27.5	32.5	52.5	57.5	91.0*
0537	(5.20)	82.5	72.5	62.5	57.5	37.5	12.5	37.5	57.5	52.5	62.5
0542	(2.55)	72.5	72.5	62.5	52.5	32.5	22.5	37.5	57.5	62.5	91.0*
0543	(3.57)	72.5	72.5	57.5	52.5	32.5	12.5	27.5	42.5	57.5	87.5
0544	(1.92)	82.5	72.5	62.5	52.5	32.5	17.5	22.5	37.5	57.5	87.5
Mean	(3.06)	77.5	73.5	61.5	54.5	35.5	18.5	31.5	49.5	57.5	83.9
S.D.	(1.36)	5.0	2.2	2.2	2.7	4.5	6.5	6.5	9.1	3.5	12.1
Animal	(Q-10 dB)					Post-Exposure					
0521	(2.47)	104.0*	80.0*	104.0*	87.5	87.5	72.5	82.5	100.0*	91.0*	91.0*
0537	(1.25)	92.5	88.0*	82.5	77.5	72.5	67.5	72.5	92.5	91.0*	91.0*
0542	(1.12)	104.0*	88.0*	104.0*	102.0*	31.0*	82.5	82.5	92.5	87.5	87.5
0543	(3.57)	72.5	72.5	57.5	52.5	42.5	22.5	37.5	57.5	67.5	91.0*
0544	(3.39)	97.5	88.0*	87.5	97.5	77.5	82.5	72.5	100.0*	91.0*	91.0*
Mean	(2.36)	94.1	84.9	87.1	83.4	74.2	65.5	69.5	88.5	85.6	90.3
S.D.	(1.15)	13.0	6.9	19.2	19.7	19.2	24.9	18.6	17.7	10.2	1.6

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 10/M

Probe Frequency: 2.0 kHz

Masker (kHz):		0.300	0.750	0.900	1.300	1.700	2.050	2.200	3.000	3.500	4.000
Animal	(Q-10 dB)					Pre-Exposure					
0521	(3.61)	82.5	62.5	57.5	52.5	47.5	32.5	37.5	57.5	67.5	87.5
0537	(5.24)	77.5	52.5	42.5	37.5	32.5	17.5	27.5	47.5	57.5	87.5
0542	(1.18)	72.5	62.5	42.5	37.5	32.5	32.5	37.5	62.5	87.0*	96.0*
0543	(2.59)	77.5	52.5	42.5	37.5	32.5	22.5	22.5	47.5	52.5	96.0*
0544	(2.36)	82.5	62.5	47.5	42.5	32.5	22.5	22.5	42.5	47.5	96.0*
Mean	(3.00)	78.5	58.5	46.5	41.5	35.5	25.5	29.5	51.5	62.4	92.6
S.D.	(1.52)	4.2	5.5	6.5	6.5	6.7	6.7	7.6	8.2	15.6	4.7
Animal	(Q-10 dB)					Post-Exposure					
0521	(4.09)	102.0*	98.0*	87.5	77.5	82.5	72.5	82.5	77.5	82.5	92.5
0537	(1.20)	92.5	77.5	72.5	82.5	82.5	87.5	82.5	96.0*	87.0*	96.0*
0542	(1.50)	102.0*	92.5	92.5	87.5	95.0*	90.0*	90.0*	82.5	82.5	96.0*
0543	(2.77)	77.5	47.5	42.5	32.5	32.5	22.5	22.5	52.5	57.5	87.5
0544	(0.58)	102.0*	87.5	82.5	77.5	82.5	82.5	77.5	87.5	87.0*	96.0*
Mean	(2.03)	95.2	80.6	75.5	71.5	75.0	71.0	71.0	79.2	79.3	93.6
S.D.	(1.40)	10.7	20.0	19.9	22.2	24.4	27.9	27.5	16.4	12.4	3.7

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 10/M

Probe Frequency: 4.0 kHz

Masker (kHz):		0.450	1.300	2.200	3.000	3.500	4.100	4.500	5.000	5.600	6.000
Animal	(Q-10 dB)					Pre-Exposure					
0521	(4.10)	77.5	57.5	52.5	52.5	27.5	17.5	27.5	42.5	57.5	72.5
0537	(6.09)	77.5	57.5	47.5	62.5	32.5	17.5	32.5	42.5	57.5	57.5
0542	(6.09)	72.5	52.5	52.5	47.5	27.5	12.5	27.5	42.5	62.5	92.0*
0543	(4.10)	77.5	67.5	47.5	47.5	32.5	22.5	32.5	47.5	52.5	62.5
0544	(2.58)	82.5	52.5	47.5	52.5	22.5	17.5	22.5	27.5	42.5	62.5
Mean	(4.59)	77.5	57.5	49.5	52.5	28.5	17.5	28.5	40.5	54.5	69.4
S.D.	(1.50)	3.5	6.1	2.7	6.1	4.2	3.5	4.2	7.6	7.6	13.8
Animal	(Q-10 dB)					Post-Exposure					
0521	(2.07)	102.0*	87.5	72.5	82.5	72.5	67.5	62.5	67.5	67.5	92.5
0537	(2.51)	82.5	62.5	62.5	62.5	42.5	37.5	42.5	47.5	67.5	92.0*
0542	(4.79)	97.5	82.5	77.5	82.5	67.5	82.5	87.5	87.5	92.5	92.0*
0543	(3.62)	82.5	52.5	52.5	47.5	27.5	22.5	32.5	47.5	47.5	67.5
0544	(9.79)	87.5	67.5	67.5	67.5	57.5	62.5	57.5	67.5	47.5	62.5
Mean	(4.56)	90.4	70.5	66.5	68.5	53.5	54.5	56.5	63.5	64.5	81.3
S.D.	(3.11)	8.9	14.4	9.6	14.7	18.5	24.1	21.0	16.7	18.6	15.0

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 10/M

Probe Frequency: 8.0 kHz

Masker (kHz):		0.450	1.300	2.500	5.900	7.000	8.100	9.300	11.000	12.700	14.000
Animal	(Q-10 dB)					Pre-Exposure					
0521	(7.80)	82.5	62.5	57.5	37.5	42.5	17.5	37.5	57.5	62.5	72.5
0537	(6.53)	87.5	72.5	67.5	47.5	52.5	27.5	42.5	92.5	100.0*	95.0*
0542	(3.57)	82.5	67.5	62.5	52.5	57.5	42.5	47.5	72.5	97.0*	95.0*
0543	(4.88)	87.5	62.5	62.5	57.5	47.5	22.5	32.5	62.5	92.5	95.0*
0544	(4.16)	82.5	57.5	57.5	42.5	42.5	22.5	27.5	72.5	97.5	95.0*
Mean	(5.39)	84.5	64.5	61.5	47.5	48.5	26.5	37.5	71.5	89.9	90.5
S.D.	(1.74)	2.7	5.7	4.2	7.9	6.5	9.6	7.9	13.4	15.6	10.1
Animal	(Q-10 dB)					Post-Exposure					
0521	(0.18)	102.0*	67.5	72.5	72.5	72.5	77.5	67.5	82.5	100.0*	95.0*
0537	(5.29)	87.5	67.5	67.5	42.5	47.5	32.5	47.5	97.5	100.0*	95.0*
0542	(0.65)	102.0*	95.0*	91.0*	87.5	87.5	92.5	94.0*	102.0*	100.0*	95.0*
0543	(3.26)	92.5	62.5	62.5	47.5	47.5	32.5	32.5	62.5	100.0*	95.0*
0544	(4.06)	82.5	62.5	62.5	47.5	62.5	42.5	47.5	82.5	100.0*	95.0*
Mean	(2.69)	93.3	71.0	71.2	59.5	63.5	55.5	57.8	85.4	100.0	95.0
S.D.	(2.20)	8.7	13.6	11.8	19.6	17.1	27.7	23.8	15.5	0.0	0.0

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 10/M

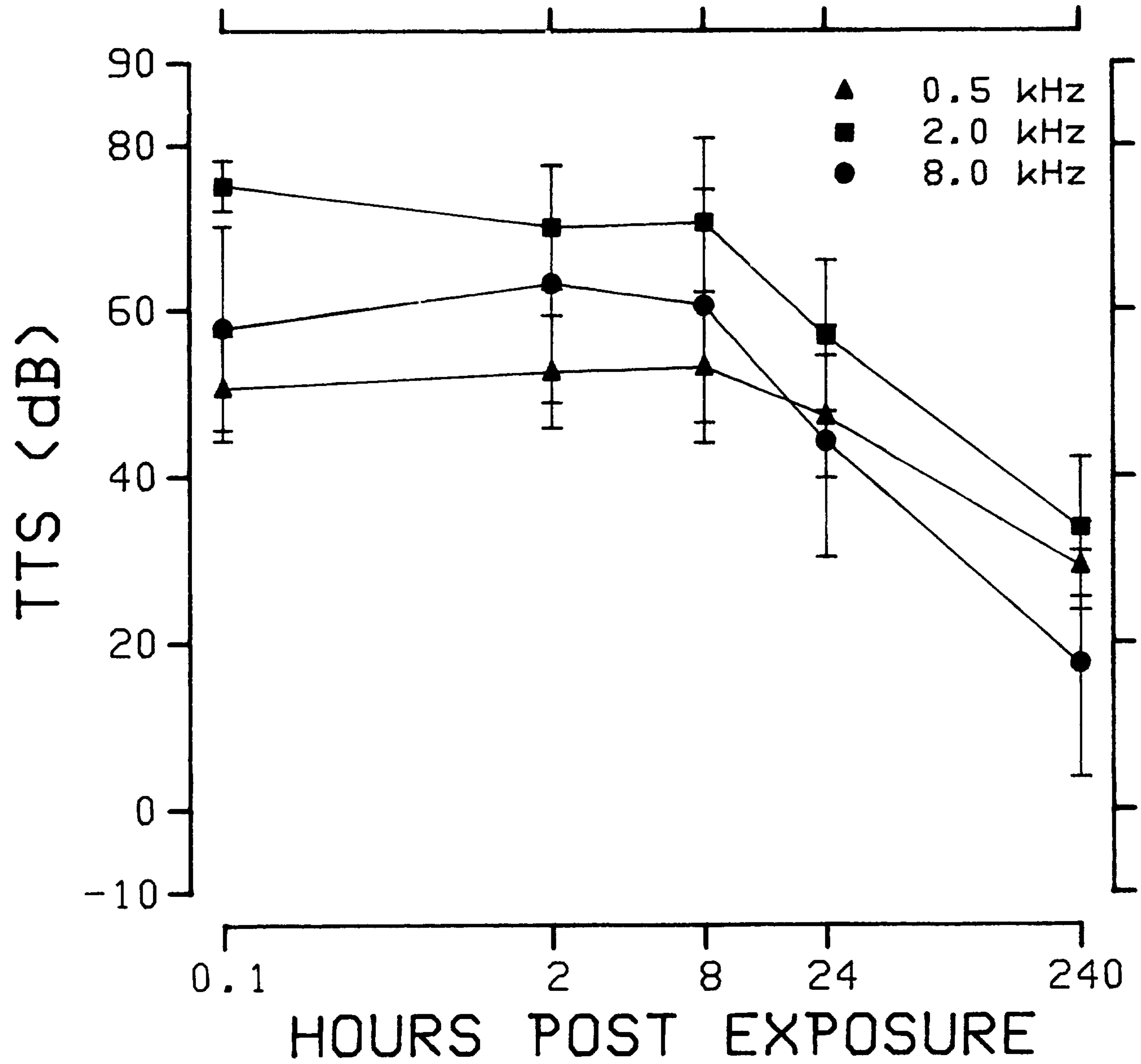
Probe Frequency: 11.2 kHz

Masker (kHz):		1.000	4.000	7.000	9.000	11.000	11.500	12.000	13.000	14.500	16.000
Animal	(Q-10 dB)					Pre-Exposure					
0521	(8.39)	67.5	57.5	57.5	47.5	27.5	22.5	37.5	47.5	57.5	87.5
0537	(3.66)	67.5	62.5	57.5	57.5	32.5	32.5	32.5	37.5	82.5	91.0*
0542	(4.62)	72.5	62.5	62.5	52.5	37.5	42.5	47.5	62.5	72.5	91.0*
0543	(6.24)	67.5	62.5	57.5	47.5	37.5	42.5	37.5	32.5	57.5	72.5
0544	(5.83)	67.5	57.5	57.5	52.5	42.5	47.5	42.5	37.5	57.5	77.5
Mean	(5.75)	68.5	60.5	58.5	51.5	35.5	37.5	39.5	43.5	65.5	83.9
S.D.	(1.80)	2.2	2.7	2.2	4.2	5.7	10.0	5.7	11.9	11.5	8.4
Animal	(Q-10 dB)					Post-Exposure					
0521	(0.67)	72.5	62.5	72.5	77.5	77.5	67.5	67.5	77.5	102.0*	91.0*
0537	(14.53)	67.5	62.5	62.5	57.5	52.5	47.5	37.5	67.5	87.5	91.0*
0542	(*****)	87.5	82.5	87.5	87.5	102.0*	97.5	92.5	92.5	102.0*	91.0*
0543	(6.60)	67.5	62.5	67.5	52.5	47.5	47.5	32.5	32.5	62.5	72.5
0544	(2.85)	62.5	57.5	52.5	47.5	32.5	32.5	32.5	32.5	62.5	72.5
Mean	(6.16)	71.5	65.5	68.5	64.5	62.4	58.5	52.5	60.5	83.3	83.6
S.D.	(6.09)	9.6	9.7	12.9	17.2	27.4	25.1	26.7	27.1	19.9	10.1

The Group Mean Recovery Curves

Measured at Three Test Frequencies

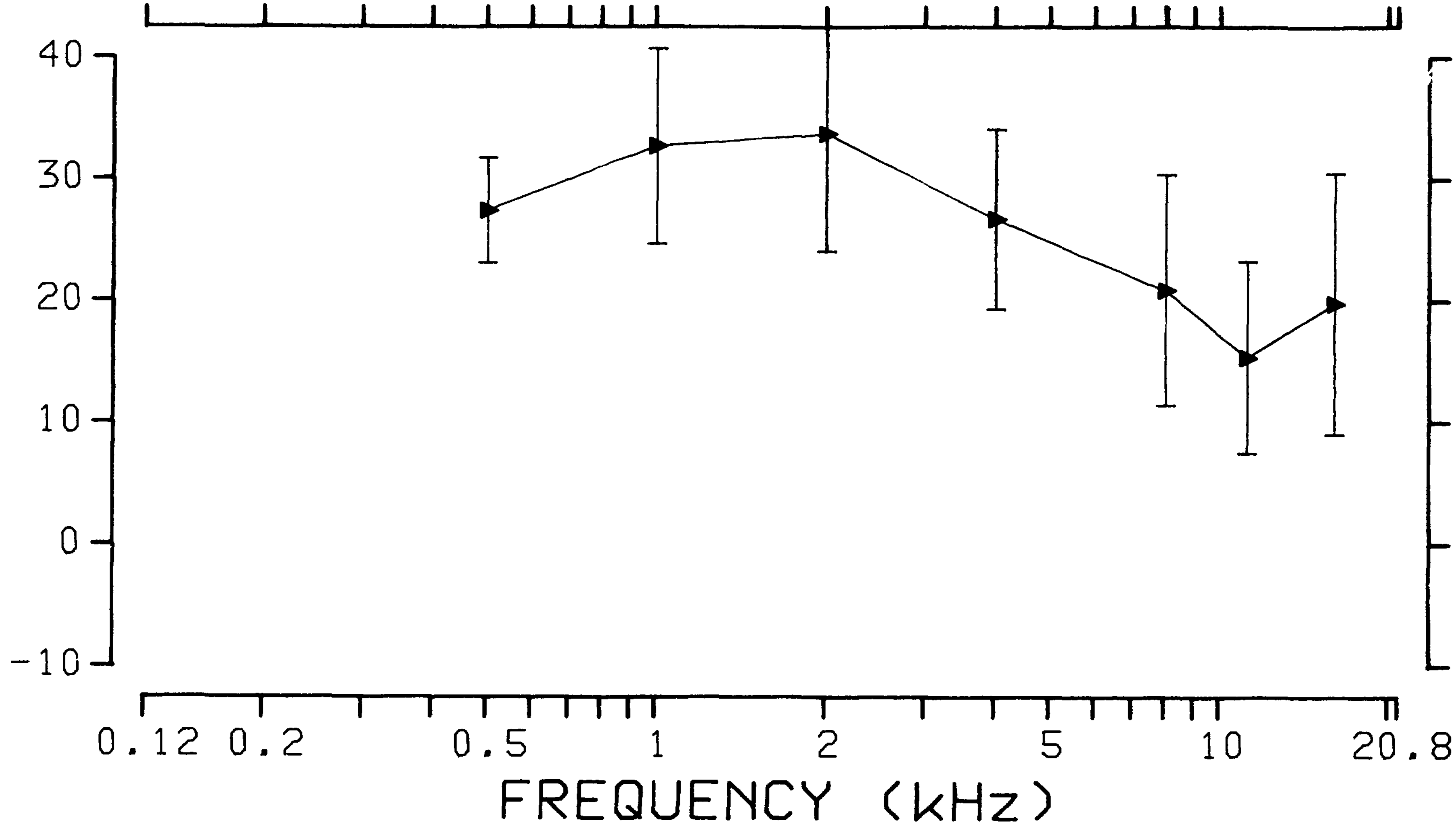
MEAN DATA (n=5) - 160 dB 100X 10/M



The Group Mean Permanent Threshold Shift (PTS)

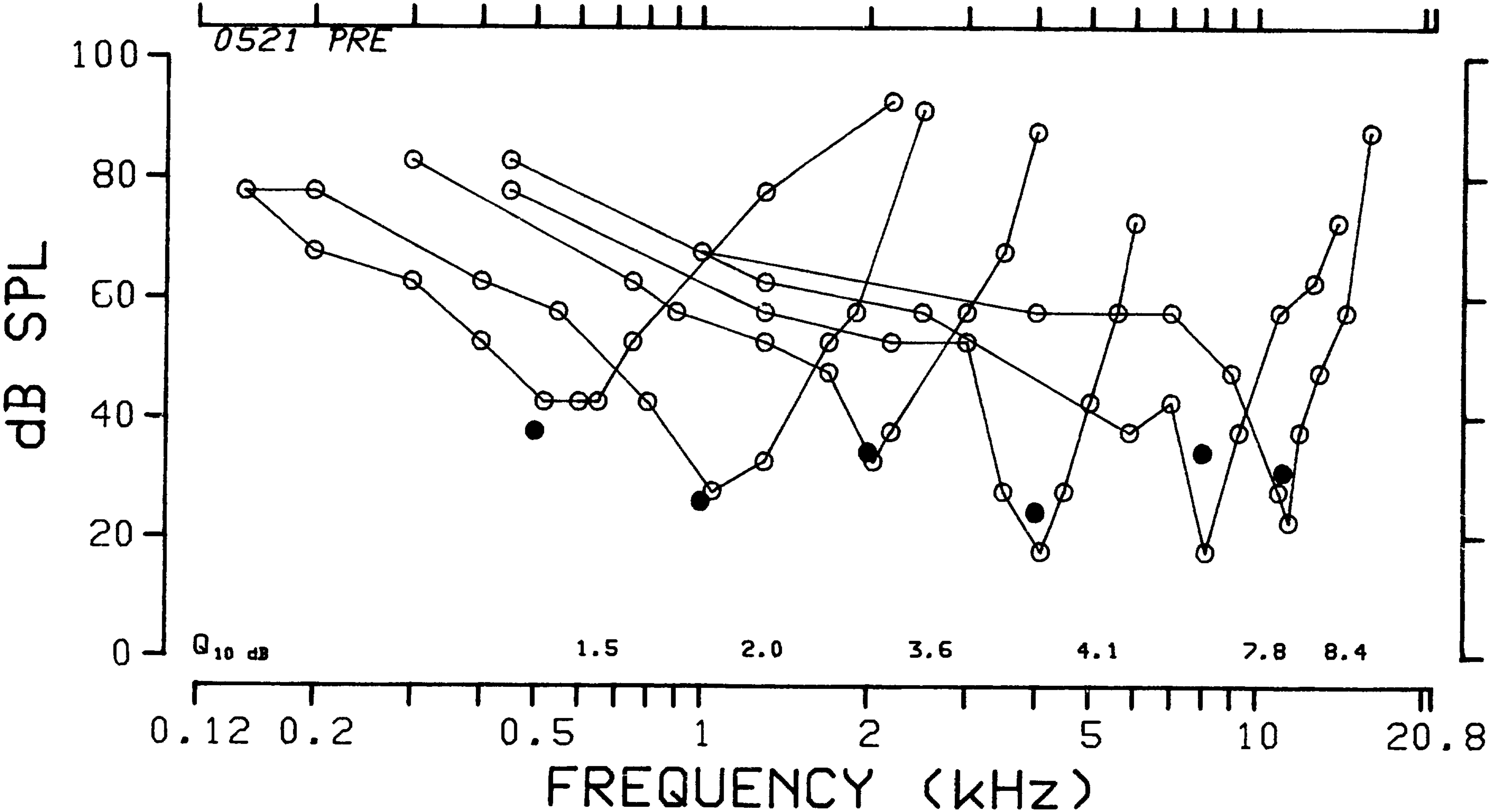
for all Test Frequencies

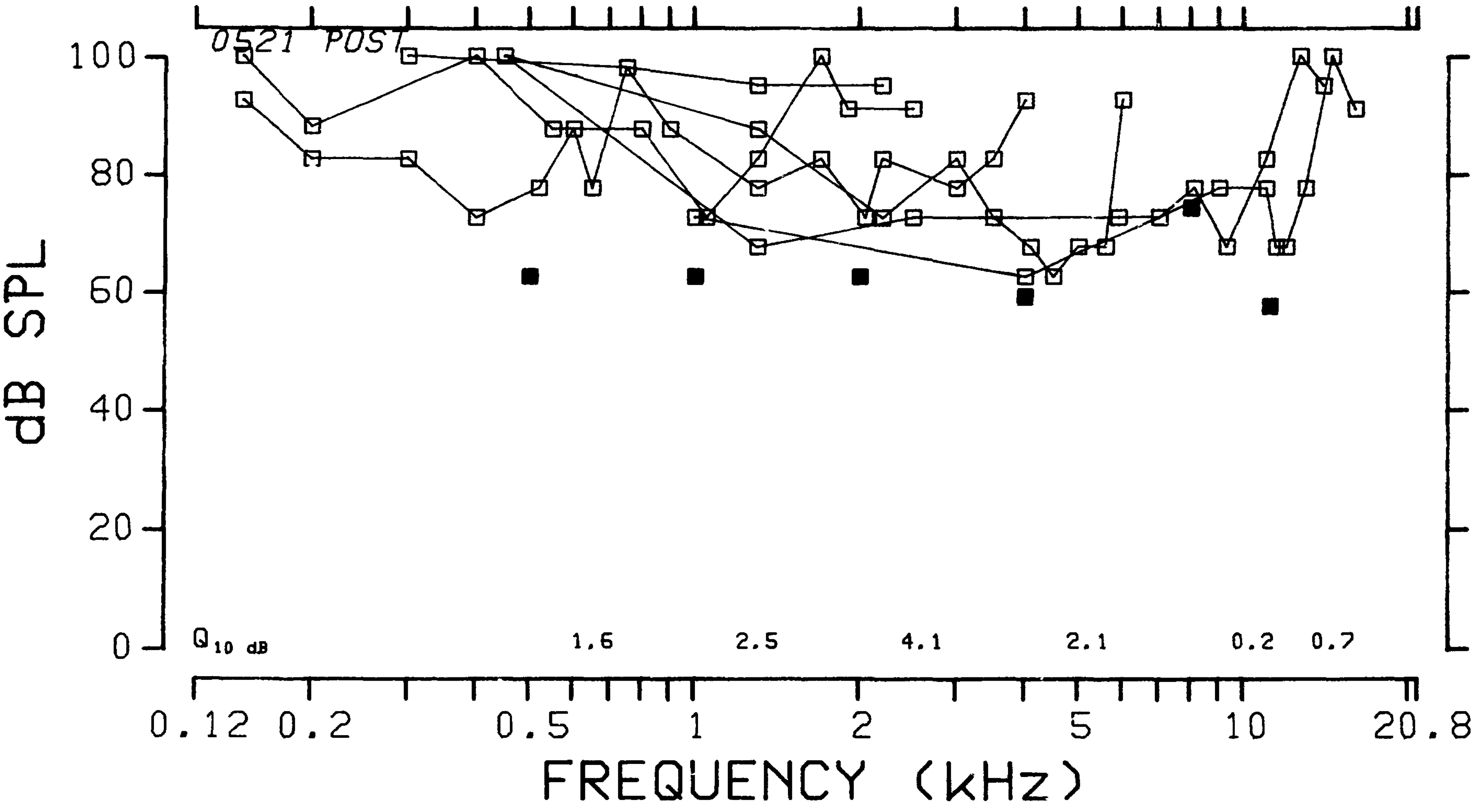
MEAN DATA (n=5) - 160 dB 100X 10/M



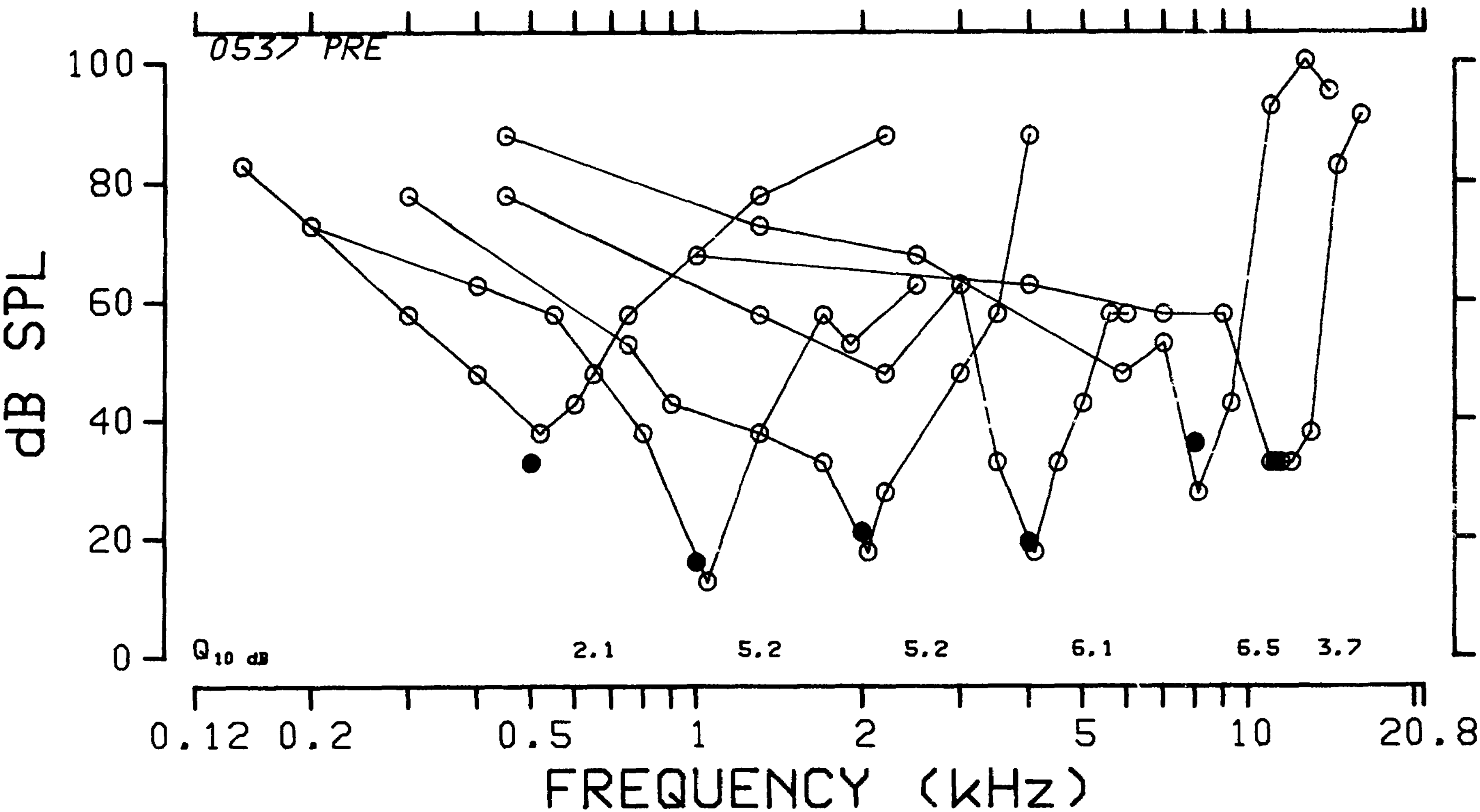
The Pre and Postexposure Tuning Curves for
Individual Animals in this Exposure Group.

The Solid Symbol represents the intensity of the probe tone.


0521 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.5
2.0
3.6
4.1
7.8
8.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

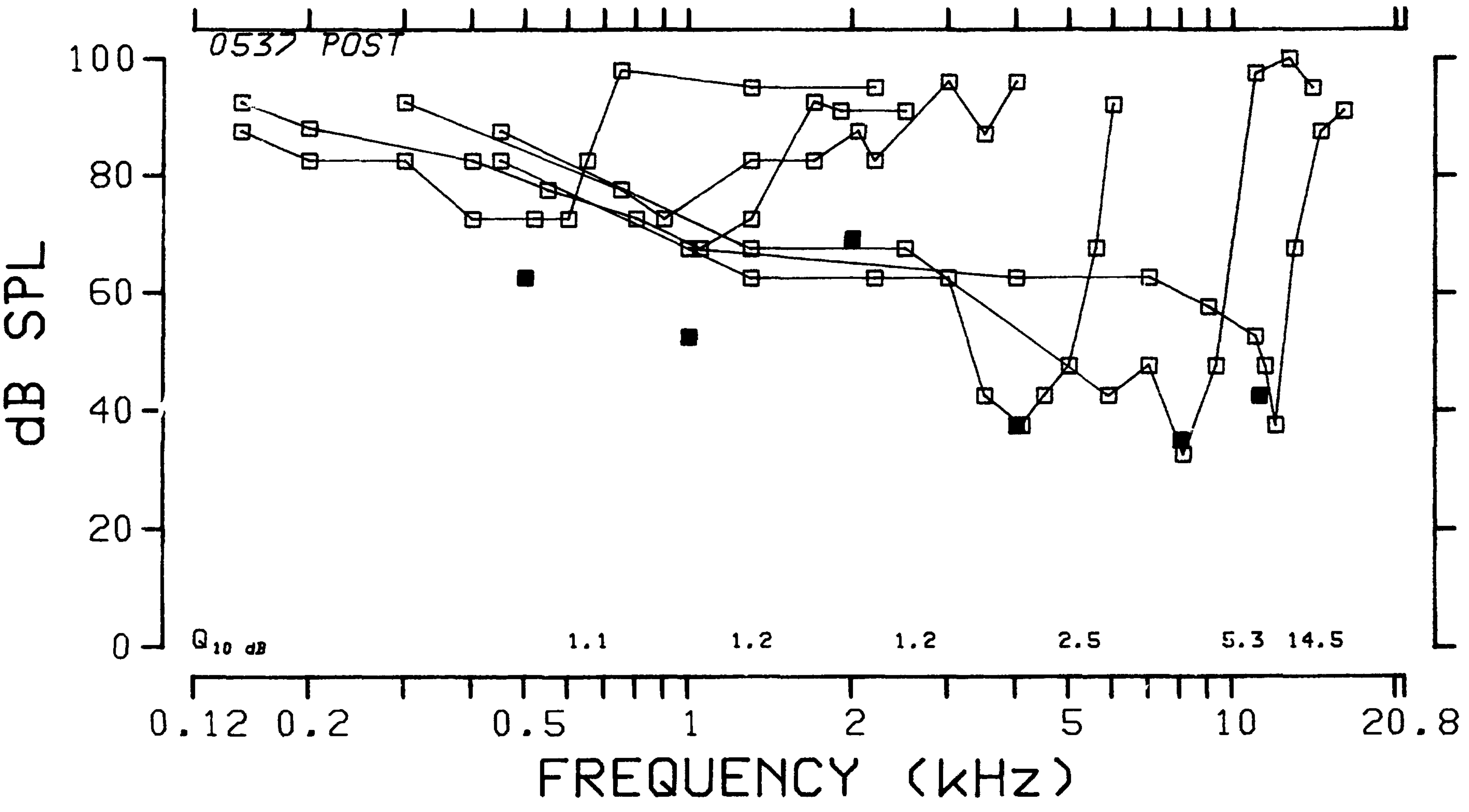


0521 POST
100
80
60
40
20
0
dB SPL
Q10 dB
1.6
2.5
4.1
2.1
0.2
0.7
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

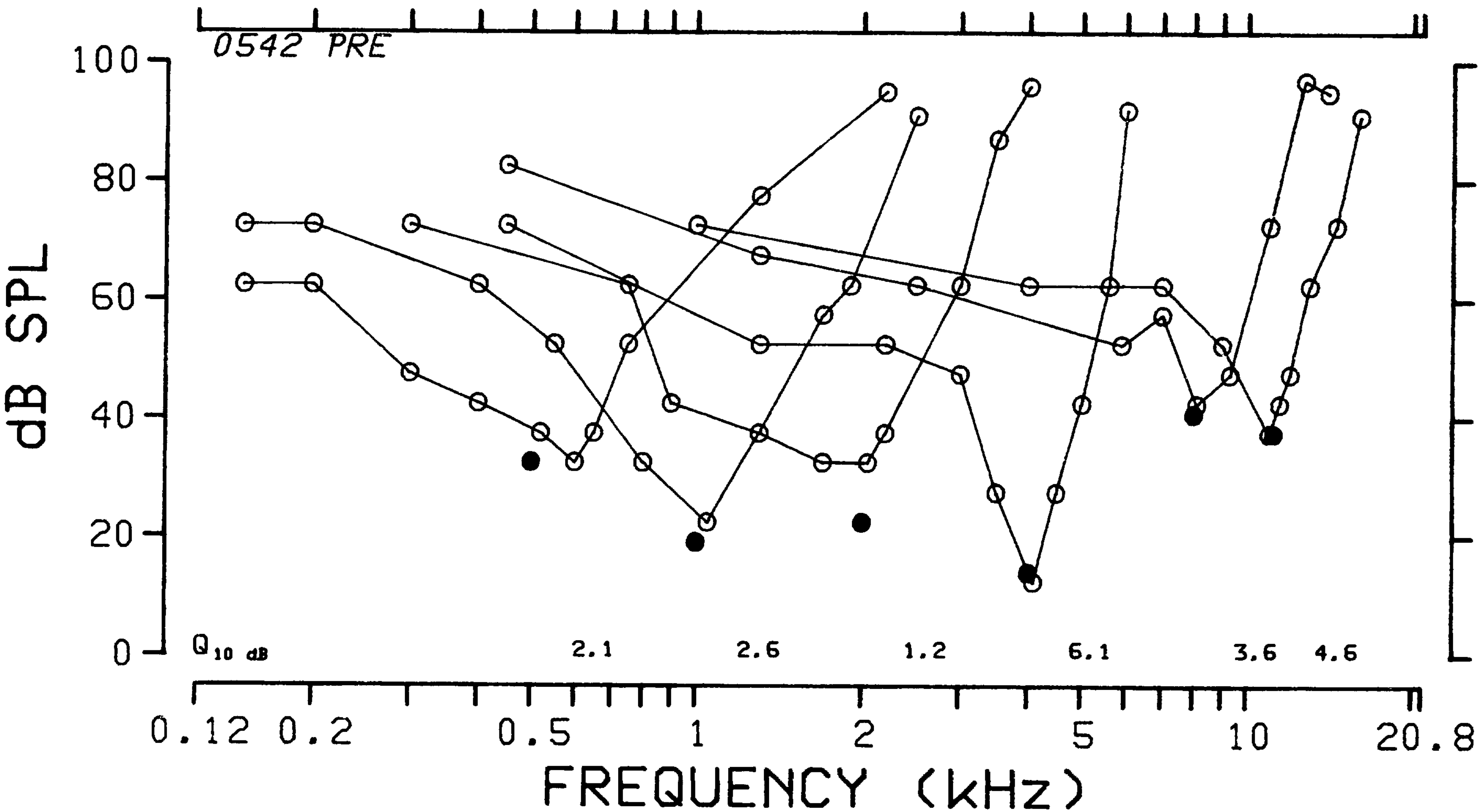


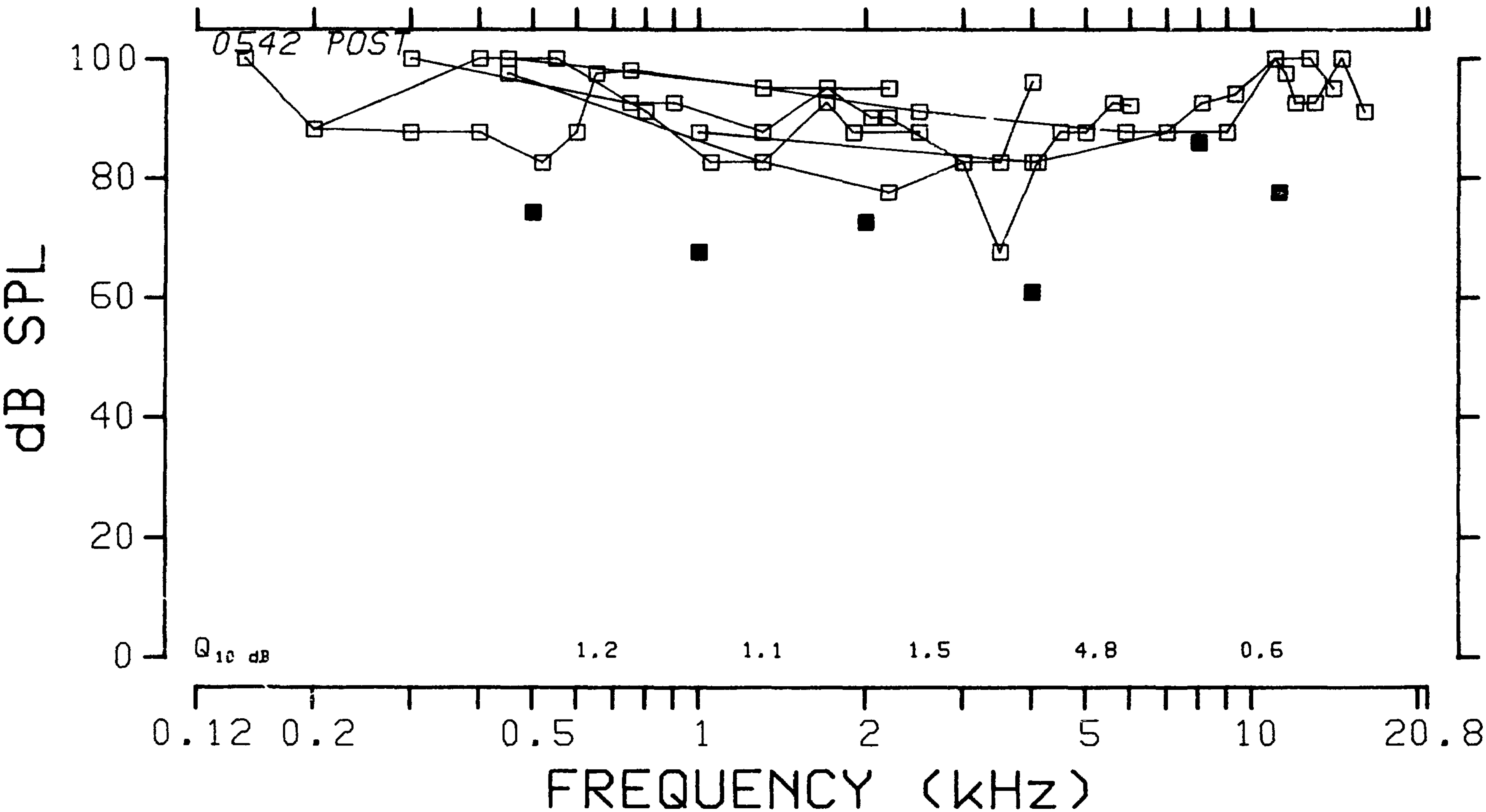
0537 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.1
5.2
5.2
6.1
6.5
3.7
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

220

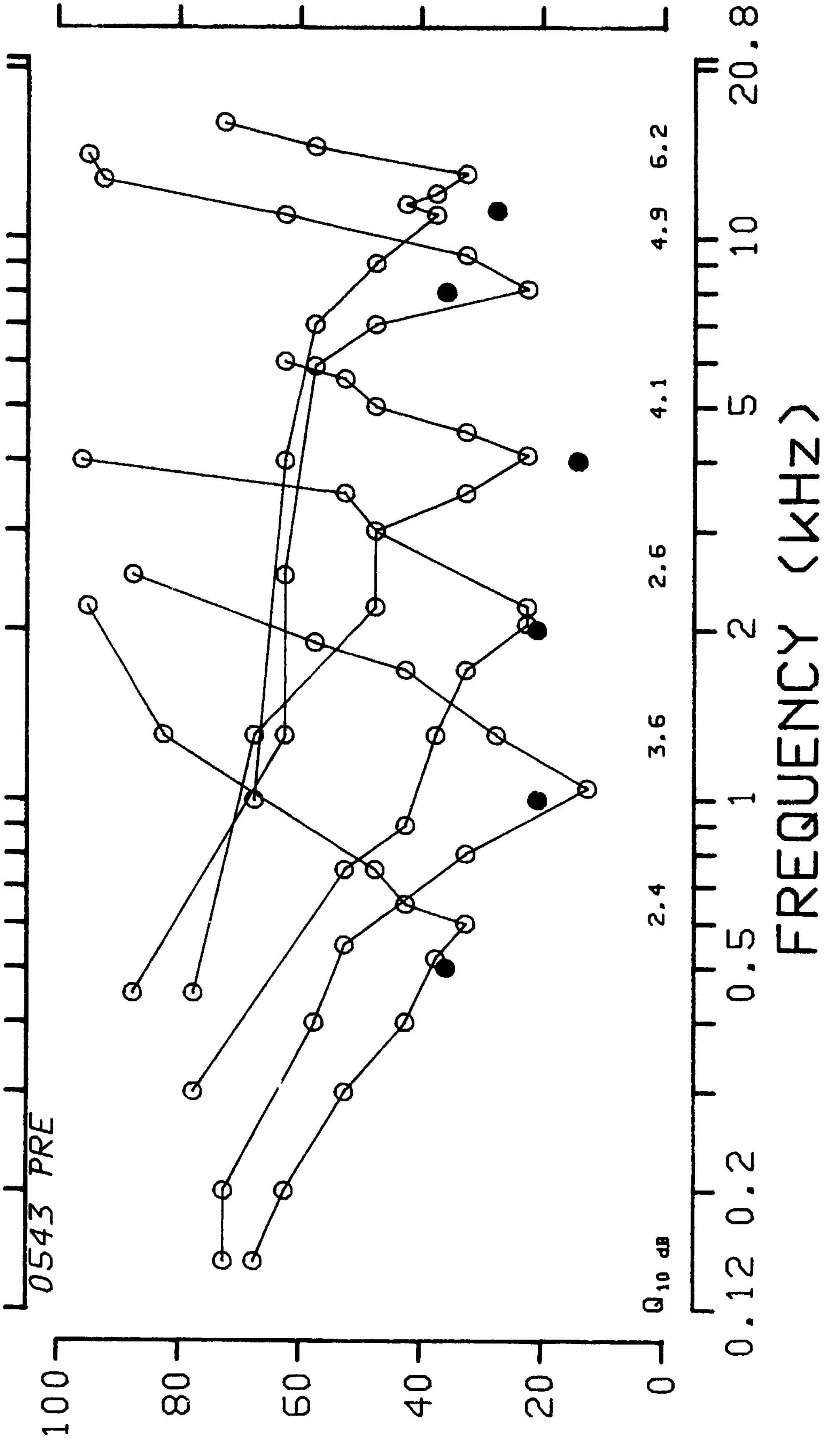

0537 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.1
1.2
1.2
2.5
5.3
14.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

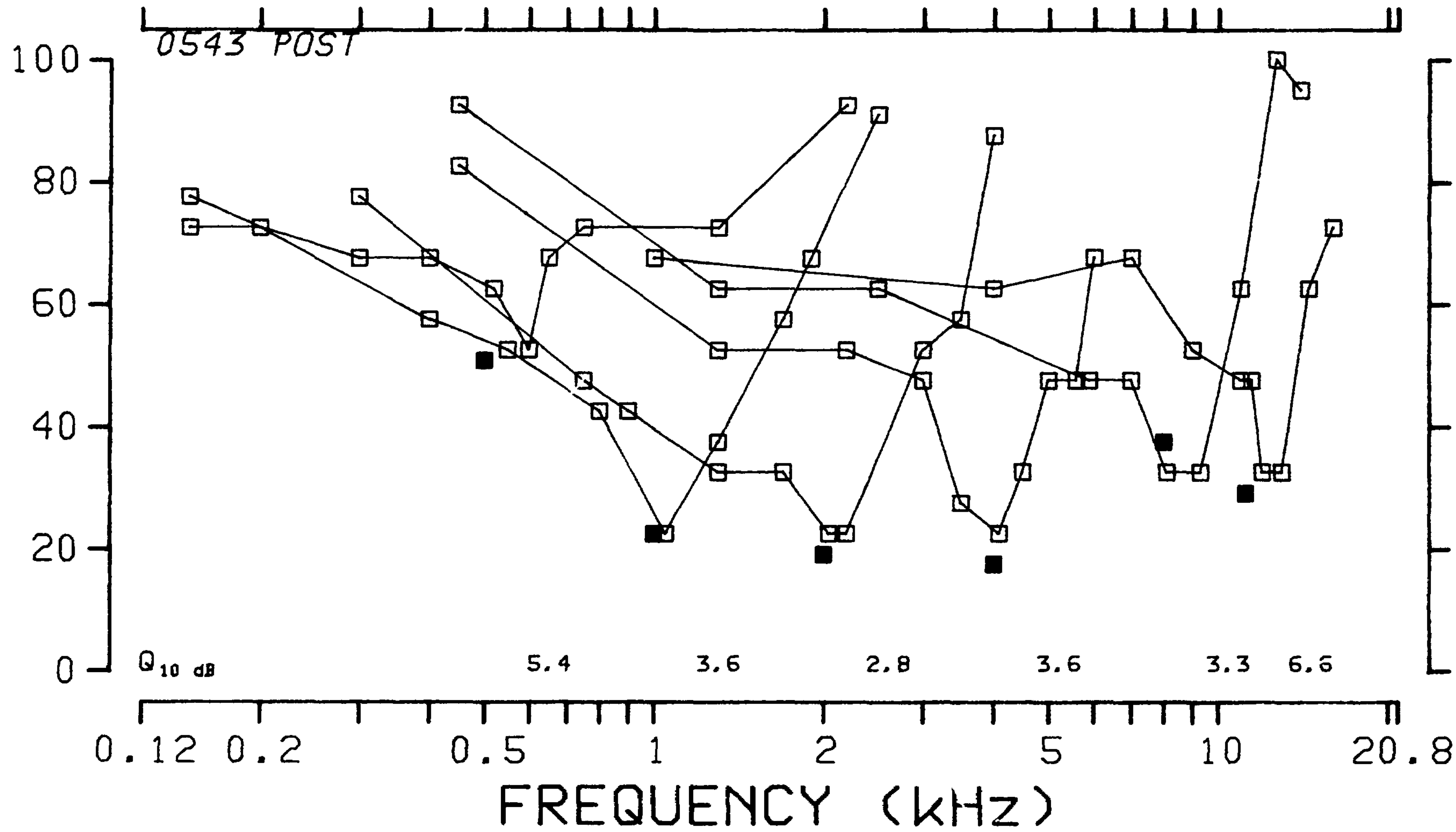
221

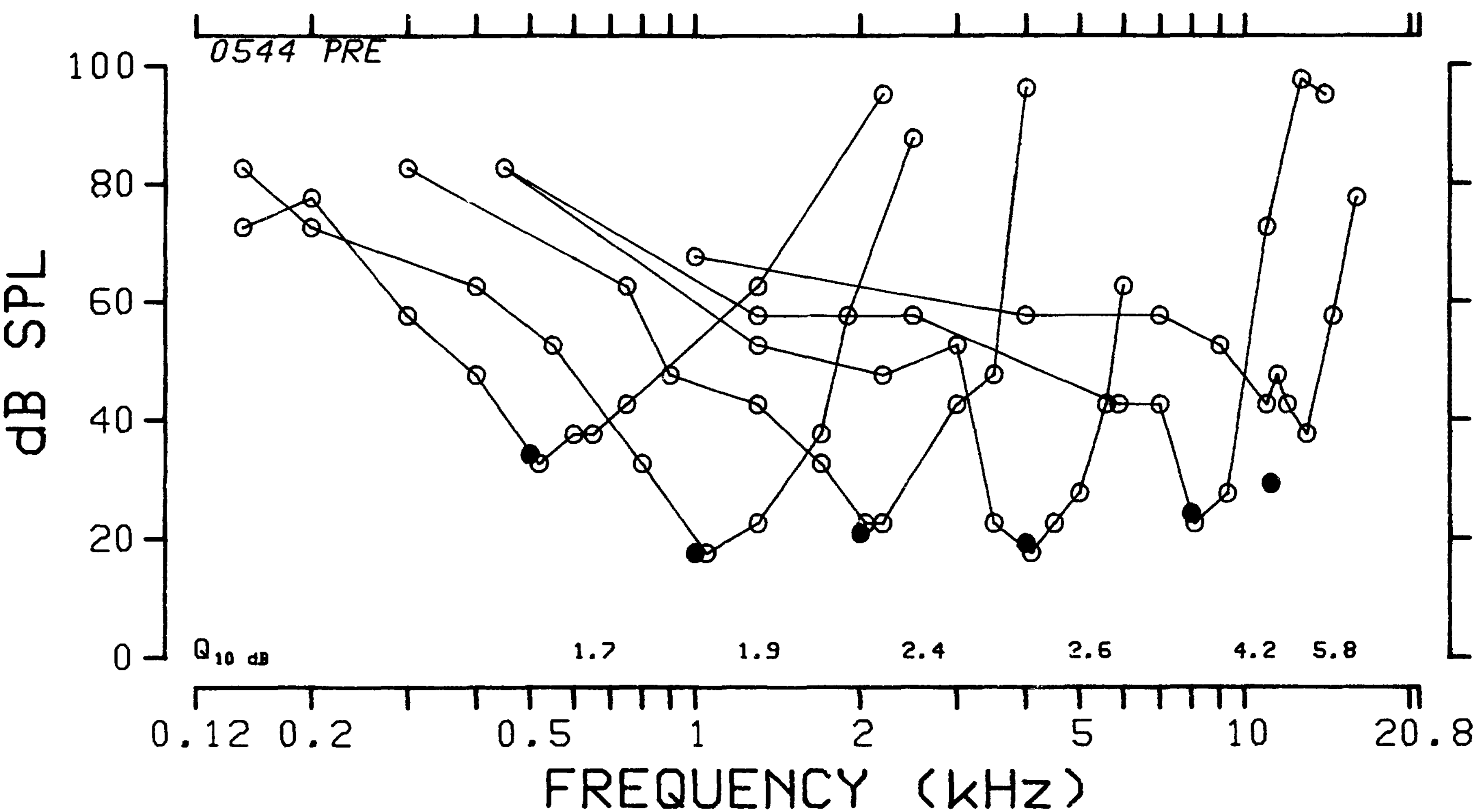

0542 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.1
2.6
1.2
6.1
3.6
4.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

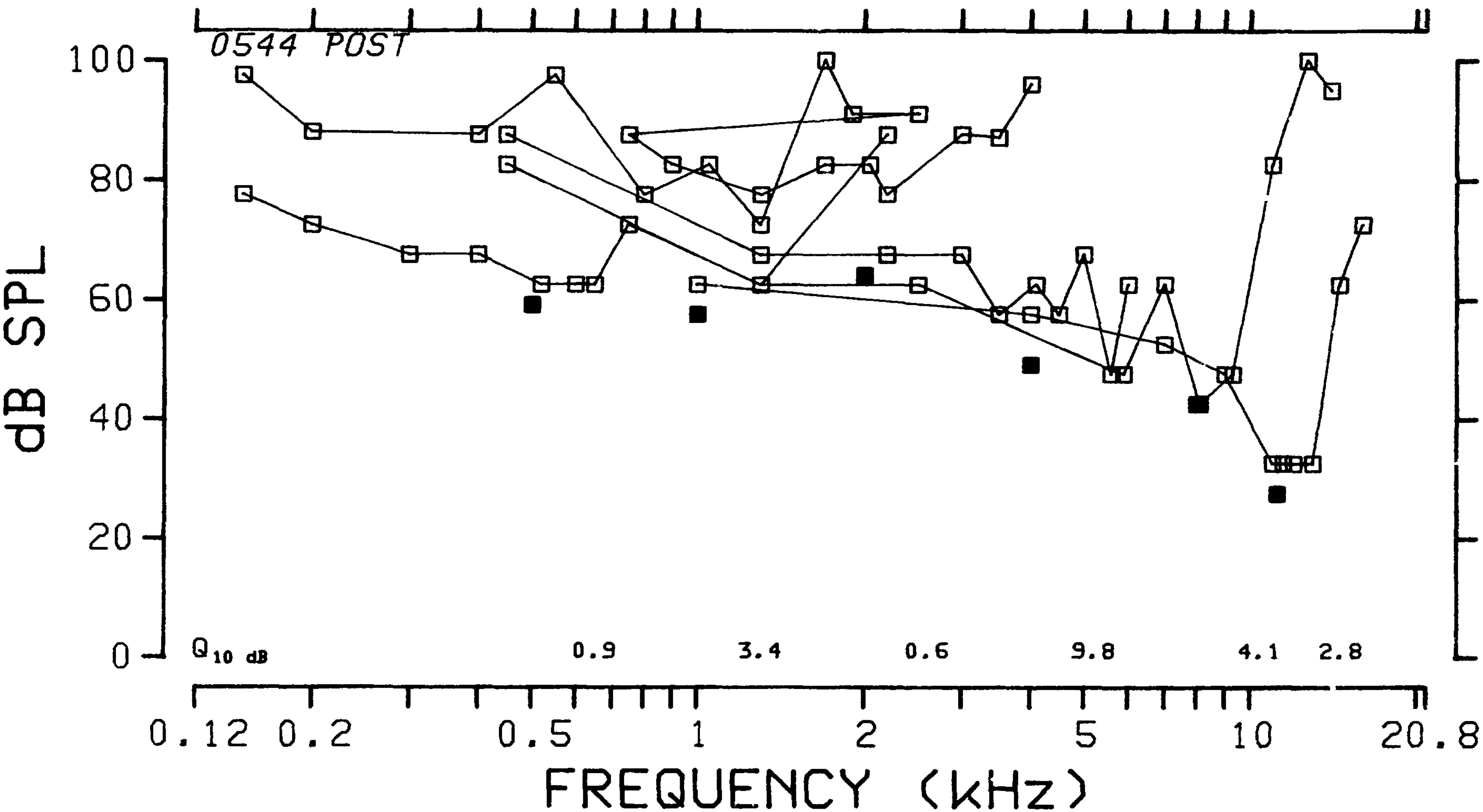


0542 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.2
1.1
1.5
4.8
0.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0543 PRE
dB SPL
100
80
60
40
20
0
FREQUENCY (kHz)
0.12
0.2
0.5
1
2
5
10
20.8
Q10 dB
2.4
3.6
2.6
4.1
4.9
6.2


0543 POST
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
5.4
3.6
2.8
3.6
3.3
6.6
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0544 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
1.7
1.9
2.4
2.6
4.2
5.8
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0544 POST
dB SPL
100
80
60
40
20
0
Q10 dB
0.9
3.4
0.6
9.8
4.1
2.8
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

160 dB 100X 10/M

TOTAL NUMBER OF COCHLEAR SENSORY CELLS MISSING

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0521	87	1265	1192	961	3418
0537	100	1025	1069	831	2925
0542	326	1915	1887	1809	5611
0543	14	259	318	345	922
0544	103	1175	1243	1164	3582
GROUP MEAN	126				3292
S.D.	118				1676
S.E.	53				749

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

	OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	OUTER HAIR CELLS
GROUP MEANS			
	0.125 kHz	7.4	57.4
	0.25 kHz	7.0	130.2
	0.5 kHz	11.4	560.0
	1 kHz	36.8	717.8
	2 kHz	27.8	684.0
	4 kHz	18.8	638.4
	8 kHz	12.4	292.6
	16 kHz	4.4	211.2
STANDARD DEVIATIONS			
	0.125 kHz	14.3	51.6
	0.25 kHz	9.4	104.2
	0.5 kHz	19.0	178.7
	1 kHz	46.8	387.2
	2 kHz	26.3	391.5
	4 kHz	26.8	400.3
	8 kHz	15.9	395.5
	16 kHz	7.1	368.5

160 dB 100X 10/M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0521							
0.125 kHz	0	2	4	5	11	0	0
0.25 kHz	8	23	6	12	41	0	1
0.5 kHz	3	217	175	84	476	0	10
1 kHz	4	286	279	222	787	5	35
2 kHz	33	295	276	156	727	3	9
4 kHz	11	284	258	294	836	30	73
8 kHz	25	137	171	170	478	16	45
16 kHz	3	21	23	18	62	0	2
TOTALS	87	1265	1192	961	3418	54	175
CHINCHILLA 0537							
0.125 kHz	1	0	7	42	49	0	7
0.25 kHz	2	44	74	112	230	0	1
0.5 kHz	0	196	162	79	437	1	6
1 kHz	88	324	319	299	942	181	119
2 kHz	7	321	297	155	773	6	7
4 kHz	1	137	210	141	488	0	13
8 kHz	0	3	0	3	6	0	0
16 kHz	1	0	0	0	0	0	0
TOTALS	100	1025	1069	831	2925	188	153
CHINCHILLA 0542							
0.125 kHz	33	24	15	24	63	1	3
0.25 kHz	23	114	76	57	247	2	6
0.5 kHz	45	290	303	261	854	79	134
1 kHz	88	297	297	297	891	87	279
2 kHz	69	303	303	303	909	48	139
4 kHz	17	302	300	274	876	3	17
8 kHz	34	300	303	303	906	31	32
16 kHz	17	285	290	290	865	12	61
TOTALS	326	1915	1887	1809	5611	263	671

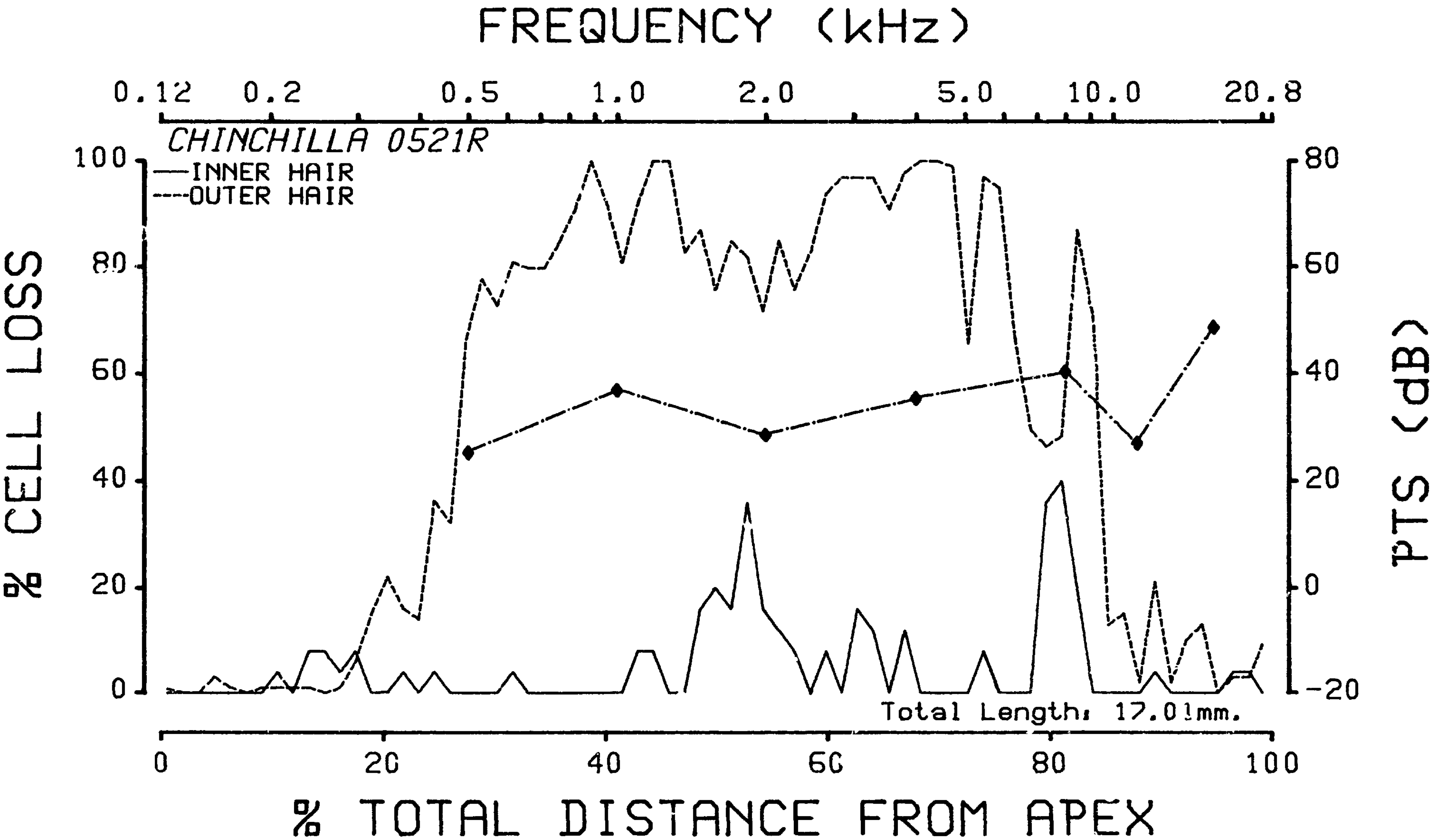
160 dB 100X 10/M

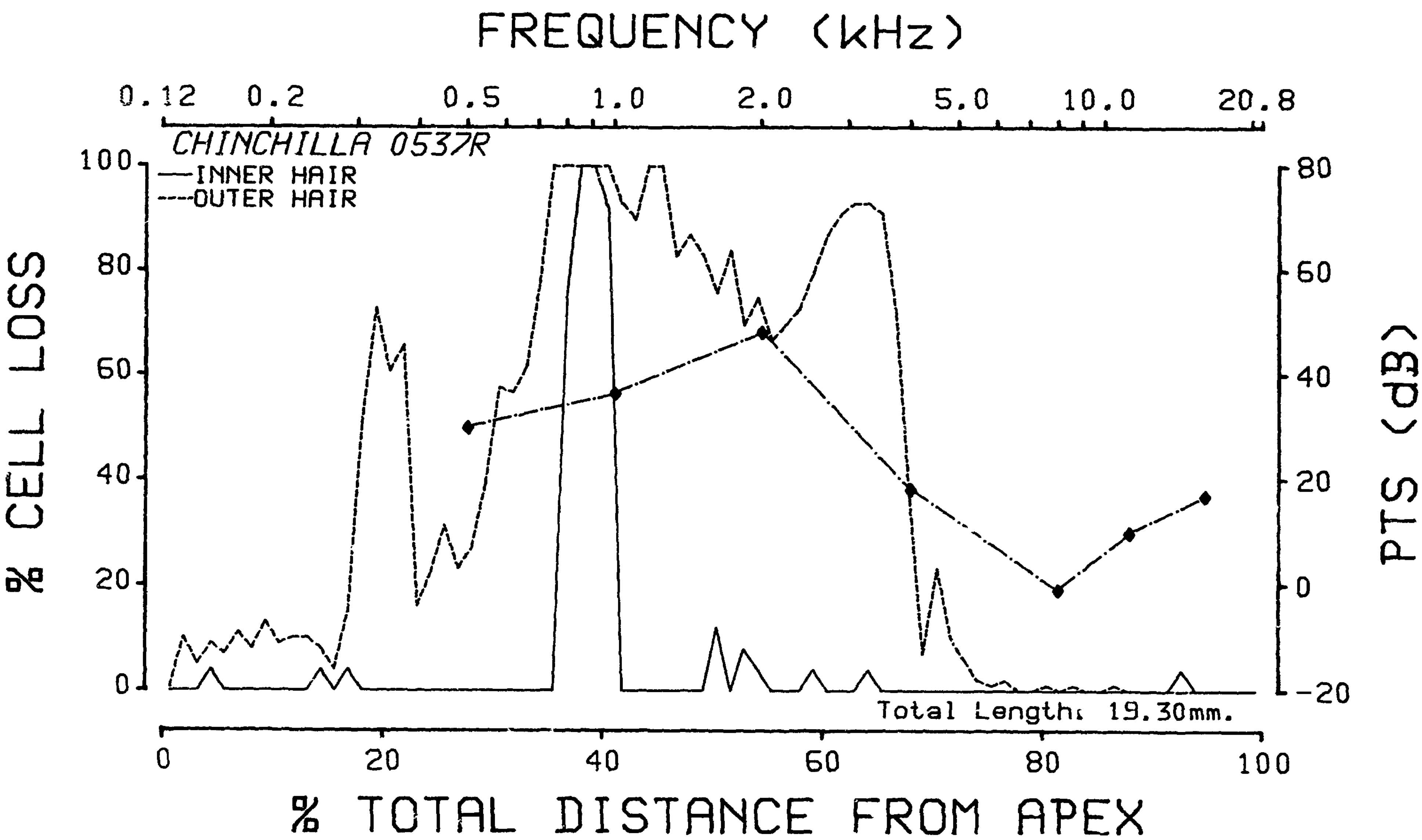
TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0543							
0.125 kHz	1	17	67	58	142	0	0
0.25 kHz	0	16	27	67	110	0	2
0.5 kHz	8	204	203	197	604	62	114
1 kHz	1	11	13	10	34	0	2
2 kHz	3	3	2	6	11	0	0
4 kHz	0	3	0	2	5	0	0
8 kHz	1	4	1	1	6	0	0
16 kHz	0	1	5	4	10	0	0
TOTALS	14	259	318	345	922	62	118
CHINCHILLA 0544							
0.125 kHz	2	7	5	10	22	0	1
0.25 kHz	2	3	6	14	23	1	0
0.5 kHz	1	137	153	139	429	0	15
1 kHz	3	321	314	300	935	0	66
2 kHz	27	336	336	328	1000	46	90
4 kHz	65	330	334	323	987	146	169
8 kHz	2	9	41	17	67	0	0
16 kHz	1	32	54	33	119	0	1
TOTALS	103	1175	1243	1164	3582	193	342
GROUP MEANS							
0.125 kHz	7.4	10.0	19.6	27.8	57.4	0.2	2.2
0.25 kHz	7.0	40.0	37.8	52.4	130.2	0.6	2.0
0.5 kHz	11.4	208.8	199.2	152.0	560.0	28.4	55.8
1 kHz	36.8	247.8	244.4	225.6	717.8	54.6	100.2
2 kHz	27.8	251.6	242.8	189.6	684.0	20.6	49.0
4 kHz	18.8	211.2	220.4	206.8	638.4	35.8	54.4
8 kHz	12.4	90.6	103.2	98.8	292.6	9.4	15.4
16 kHz	4.4	67.8	74.4	69.0	211.2	2.4	12.8
TOTALS	126.0	1127.8	1141.8	1022.0	3291.6	152.0	291.8

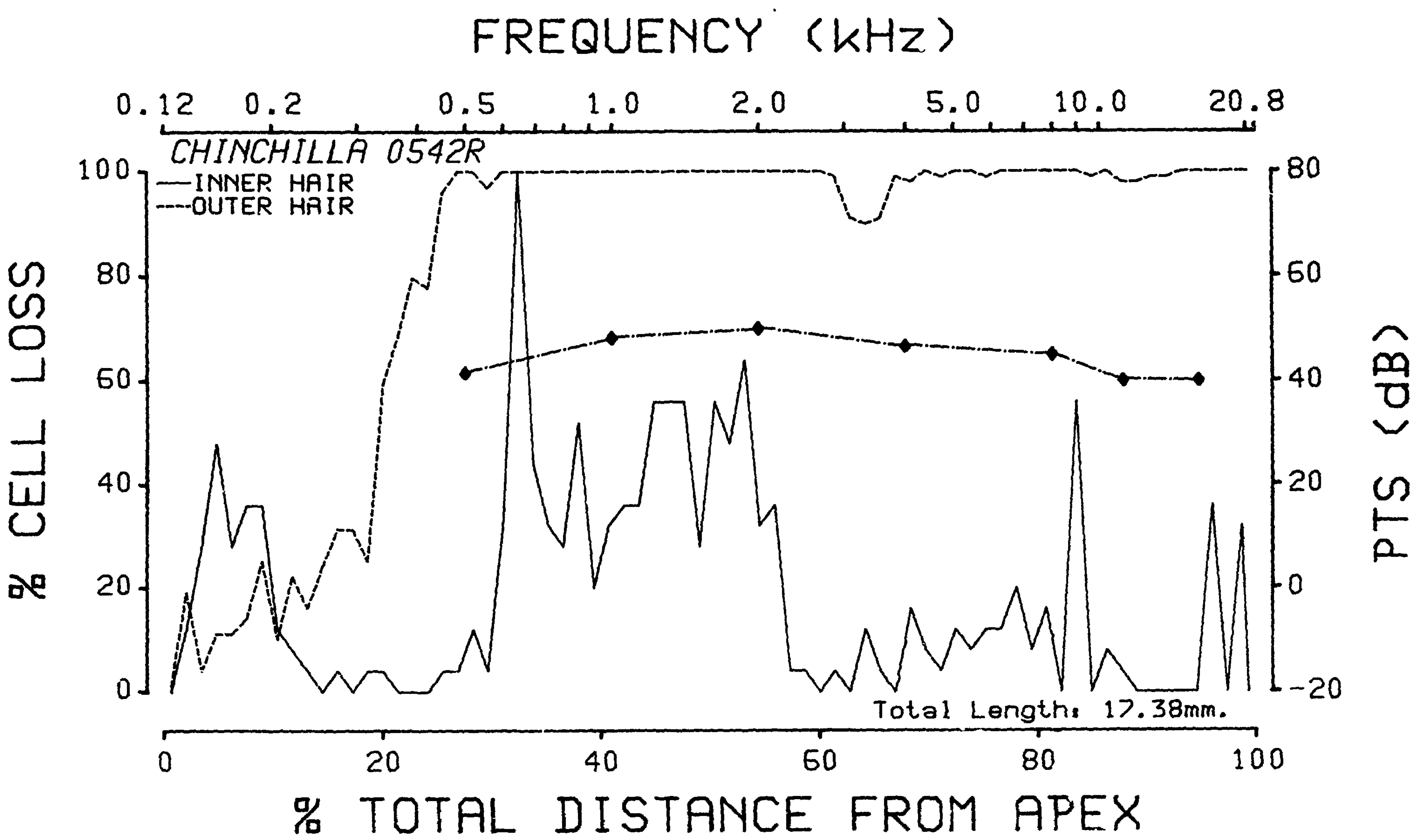
Cochleograms and PTS Audiograms

for Individual Animals

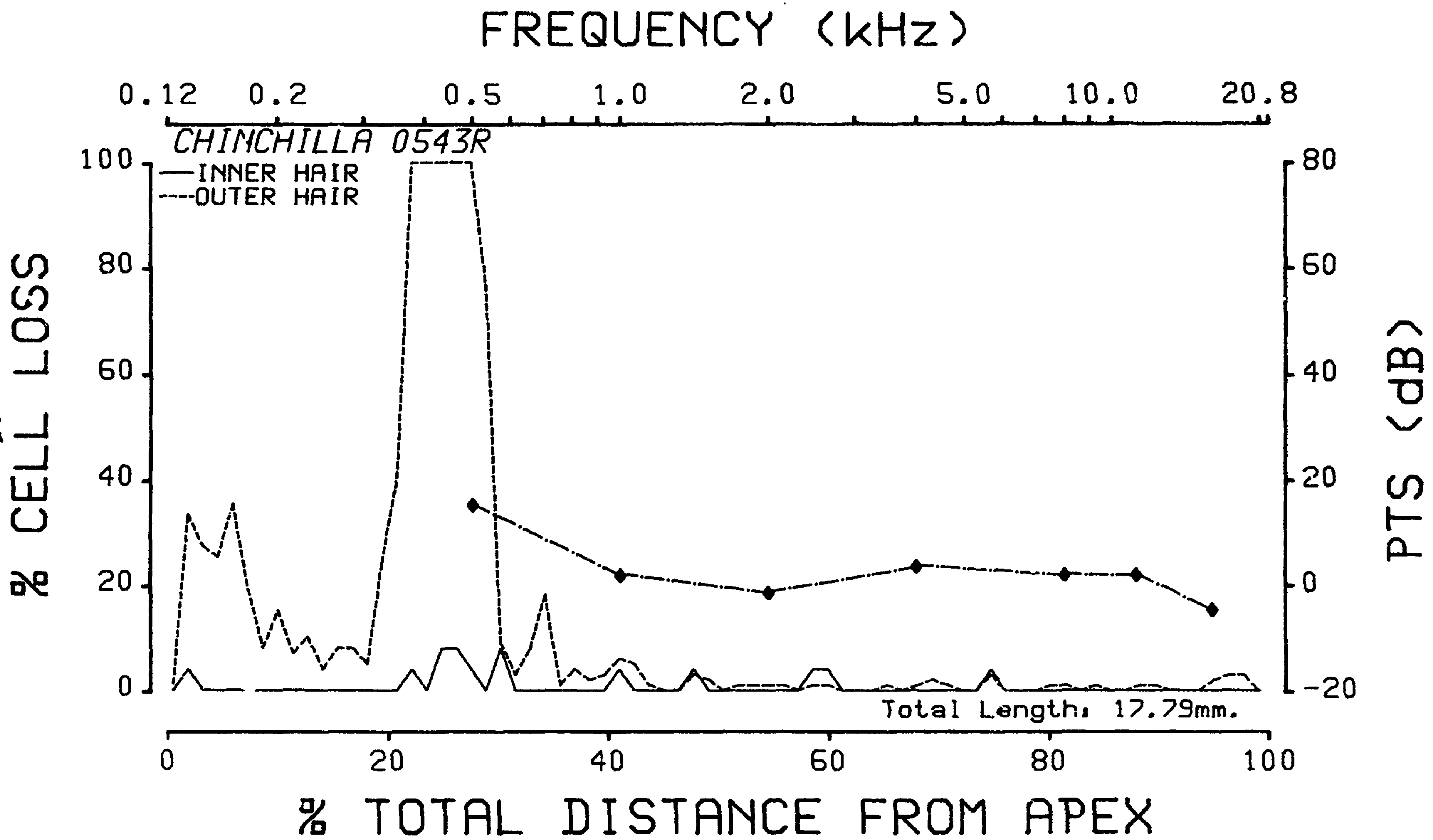

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0521R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.01mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

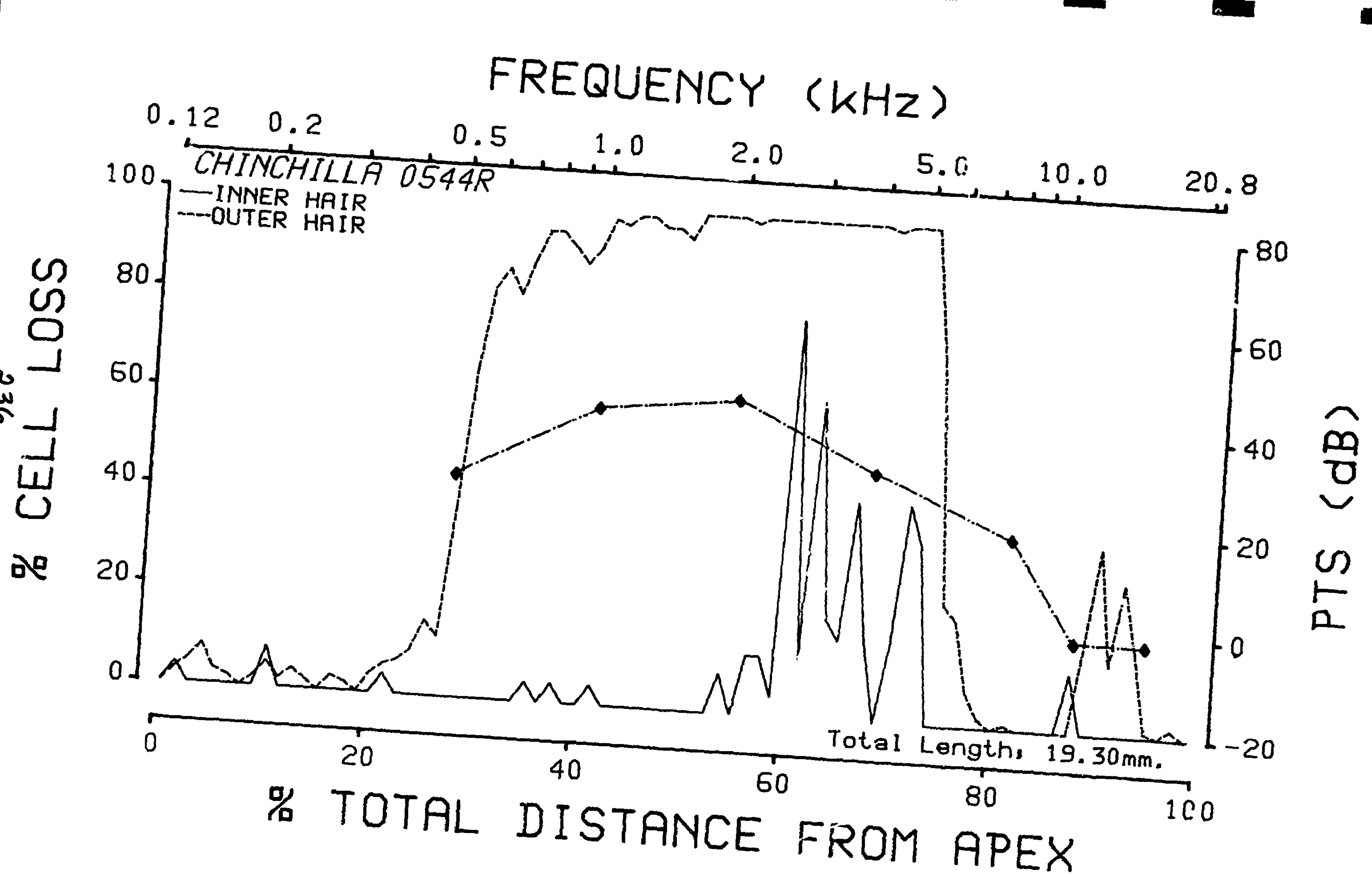


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0537R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 19.30mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0542R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.38mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0543R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.79mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0544R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length, 19.30mm.
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100

Summary Data for the Group Exposed to:

160 dB, 100X, 1/10M

Animal #		
0546	-	Completed the Entire Protocol
0547	-	Completed the Entire Protocol
0548	-	Completed the Entire Protocol
0549	-	Completed the Entire Protocol
0550	-	Completed the Entire Protocol

160 dB 100X 1/10M

PRE-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0546	22.5	7.5	14.2	2.5	17.5	24.2	22.5
0547	22.5	5.8	9.2	4.2	22.5	14.2	25.8
0548	20.8	2.5	14.2	4.2	15.8	19.2	20.8
0549	24.2	9.2	12.5	9.2	25.8	22.5	17.5
0550	23.8	12.5	12.5	7.5	12.5	5.8	5.8
Mean	22.8	7.5	12.5	5.5	18.8	17.2	18.5
S.D.	1.3	3.7	2.0	2.7	5.3	7.4	7.7

POST-EXPOSURE THRESHOLDS (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0546	60.8	47.5	54.2	47.5	75.8	82.5	70.8
0547	57.5	52.5	69.2	55.8	75.8	70.8	89.8
0548	24.2	19.2	20.8	19.2	37.5	24.2	32.5
0549	30.8	25.8	20.8	10.8	30.8	17.5	24.2
0550	34.2	37.5	34.2	7.5	15.8	7.5	4.2
Mean	41.5	36.5	39.8	28.2	47.2	40.5	44.3
S.D.	16.6	14.1	21.3	22.1	27.3	33.8	35.1

PERMANENT THRESHOLD SHIFT (dB)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
0546	38.3	40.0	40.0	45.0	58.3	58.3	48.3
0547	35.0	46.7	60.0	51.7	53.3	56.7	64.0
0548	3.3	16.7	6.7	15.0	21.7	5.0	11.7
0549	6.7	16.7	8.3	1.7	5.0	-5.0	6.7
0550	10.4	25.0	21.7	0.0	3.3	1.7	-1.7
Mean	18.7	29.0	27.3	22.7	28.3	23.3	25.8
S.D.	16.6	13.7	22.6	24.3	26.2	31.4	28.7

160 dB 100X 1/10M

TEMPORARY THRESHOLD SHIFT (dB)

Frequency 0.5 kHz

Animal\Hr	0	2	8	24	240	Max
0546	65.0	65.0	60.0	40.0	45.0	65.0
0547	72.5*	72.5*	72.5*	70.0	35.0	72.5
0548	6.7	6.7	6.7	1.7	1.7	6.7
0549	28.3	18.3	13.3	13.3	3.3	28.3
0550	23.8	18.7	8.7	8.7	13.8	23.8
Mean	39.3	36.3	32.3	26.8	19.8	39.3
S.D.	28.2	30.2	31.4	28.2	19.4	28.2

Frequency 2.0 kHz

Animal\Hr	0	2	8	24	240	Max
0546	73.8*	73.8*	68.3	73.8*	58.3	73.8
0547	78.8*	78.8*	78.8*	78.8*	68.3	78.8
0548	23.3	23.3	13.3	13.3	13.3	23.3
0549	40.0	25.0	20.0	10.0	10.0	40.0
0550	60.0	40.0	40.0	30.0	20.0	60.0
Mean	55.2	48.2	44.1	41.2	34.0	55.2
S.D.	23.3	26.5	28.9	33.0	27.3	23.3

Frequency 8.0 kHz

Animal\Hr	0	2	8	24	240	Max
0546	70.0	78.5*	70.0	70.0	65.0	78.5
0547	73.5*	73.5*	73.5*	73.5*	55.0	73.5
0548	61.7	46.7	36.7	31.7	26.7	61.7
0549	51.7	26.7	16.7	6.7	6.7	51.7
0550	45.0	20.0	20.0	20.0	5.0	45.0
Mean	60.4	49.1	43.4	40.4	31.7	62.1
S.D.	12.0	26.5	27.0	30.0	27.5	14.1

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 1/10M

Probe Frequency: 0.5 kHz

Masker (kHz):		0.150	0.200	0.300	0.400	0.520	0.600	0.650	0.750	1.300	2.200
Animal	(Q-10 dB)					Pre-Exposure					
0546	(0.67)	67.5	67.5	57.5	52.5	47.5	42.5	42.5	47.5	52.5	67.5
0547	(0.81)	82.5	82.5	57.5	47.5	42.5	42.5	47.5	42.5	62.5	95.0*
0548	(1.29)	67.5	62.5	52.5	47.5	37.5	37.5	42.5	42.5	82.5	95.0*
0549	(1.25)	77.5	62.5	52.5	47.5	42.5	42.5	42.5	57.5	67.5	95.0*
0550	(2.01)	77.5	62.5	52.5	47.5	42.5	37.5	42.5	52.5	67.5	95.0*
Mean	(1.21)	74.5	67.5	54.5	48.5	42.5	40.5	43.5	48.5	66.5	89.5
S.D.	(0.53)	6.7	8.7	2.7	2.2	3.5	2.7	2.2	6.5	10.8	12.3
Animal	(Q-10 dB)					Post-Exposure					
0546	(*****)	97.5	88.0*	87.5	97.5	82.5	87.5	92.5	87.5	77.5	77.5
0547	(0.72)	87.5	88.0*	82.5	82.5	77.5	77.5	77.5	82.5	95.0*	95.0*
0548	(1.49)	72.5	62.5	52.5	47.5	37.5	42.5	42.5	47.5	97.5	95.0*
0549	(1.07)	57.5	62.5	47.5	47.5	42.5	42.5	42.5	52.5	57.5	82.5
0550	(2.94)	67.5	67.5	62.5	52.5	57.5	42.5	42.5	52.5	82.5	82.5
Mean	(1.55)	76.5	73.7	66.5	65.5	59.5	58.5	59.5	64.5	82.0	86.5
S.D.	(0.98)	16.0	13.2	17.8	23.1	20.2	22.2	23.9	18.9	16.0	8.0

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 1/10M

Probe Frequency: 1.0 kHz

Masker (kHz):		0.150	0.200	0.400	0.550	0.800	1.050	1.300	1.700	1.900	2.500
Animal	(Q-10 dB)					Pre-Exposure					
0546	(1.72)	72.5	62.5	52.5	47.5	37.5	22.5	22.5	42.5	52.5	72.5
0547	(2.10)	77.5	67.5	57.5	52.5	37.5	27.5	37.5	62.5	62.5	91.0*
0548	(2.17)	72.5	67.5	57.5	42.5	32.5	17.5	22.5	52.5	62.5	82.5
0549	(2.55)	67.5	62.5	52.5	47.5	32.5	22.5	37.5	42.5	52.5	72.5
0550	(2.73)	87.5	77.5	67.5	67.5	42.5	22.5	32.5	57.5	72.5	91.0*
Mean	(2.25)	75.5	67.5	57.5	51.5	36.5	22.5	30.5	51.5	60.5	81.9
S.D.	(0.40)	7.6	6.1	6.1	9.6	4.2	3.5	7.6	8.9	8.4	9.3
Animal	(Q-10 dB)					Post-Exposure					
0546	(2.97)	92.5	88.0*	87.5	92.5	82.5	77.5	67.5	87.5	87.5	91.0*
0547	(1.51)	97.5	88.0*	92.5	92.5	87.5	82.5	95.0*	100.0*	91.0*	91.0*
0548	(2.55)	72.5	72.5	62.5	67.5	52.5	42.5	57.5	100.0*	91.0*	91.0*
0549	(0.93)	77.5	77.5	67.5	57.5	42.5	42.5	47.5	57.5	72.5	91.0*
0550	(1.62)	82.5	82.5	77.5	87.5	62.5	57.5	62.5	82.5	91.0*	91.0*
Mean	(1.92)	84.5	81.7	77.5	79.5	65.5	60.5	66.0	85.5	86.6	91.0
S.D.	(0.83)	10.4	6.8	12.7	16.0	19.2	18.9	17.8	17.4	8.0	0.0

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 1/10M

Probe Frequency: 2.0 kHz

Masker (kHz):		0.300	0.750	0.900	1.300	1.700	2.050	2.200	3.000	3.500	4.000
Animal	(Q-10 dB)					Pre-Exposure					
0546	(3.20)	82.5	57.5	42.5	32.5	37.5	27.5	32.5	57.5	52.5	67.5
0547	(3.25)	82.5	52.5	47.5	37.5	42.5	27.5	32.5	47.5	47.5	82.5
0548	(2.77)	82.5	57.5	47.5	37.5	42.5	32.5	37.5	52.5	67.5	87.5
0549	(4.09)	82.5	62.5	52.5	42.5	32.5	22.5	32.5	42.5	52.5	96.0*
0550	(1.38)	77.5	52.5	47.5	37.5	37.5	32.5	37.5	47.5	62.5	96.0*
Mean	(2.94)	81.5	56.5	47.5	37.5	38.5	28.5	34.5	49.5	56.5	85.9
S.D.	(1.00)	2.2	4.2	3.5	3.5	4.2	4.2	2.7	5.7	8.2	11.8
Animal	(Q-10 dB)					Post-Exposure					
0546	(1.37)	102.0*	92.5	87.5	82.5	92.5	92.5	92.5	96.0*	87.0*	96.0*
0547	(*****)	102.0*	98.0*	97.5	92.5	100.0*	95.0*	95.0*	96.0*	87.0*	96.0*
0548	(2.04)	72.5	47.5	42.5	42.5	42.5	32.5	32.5	47.5	52.5	82.5
0549	(2.59)	77.5	57.5	52.5	47.5	42.5	32.5	32.5	57.5	62.5	82.5
0550	(2.36)	72.5	62.5	57.5	52.5	52.5	42.5	42.5	62.5	67.5	96.0*
Mean	(2.09)	85.3	71.6	67.5	63.5	66.0	59.0	59.0	71.9	71.3	90.6
S.D.	(0.53)	15.4	22.3	23.7	22.5	28.0	32.0	32.0	22.7	15.3	7.4

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 1/10M

Probe Frequency: 4.0 kHz

Masker (kHz):		0.450	1.300	2.200	3.000	3.500	4.100	4.500	5.000	5.600	6.000
Animal	(Q-10 dB)					Pre-Exposure					
0546	(2.89)	77.5	57.5	47.5	47.5	32.5	27.5	32.5	42.5	52.5	52.5
0547	(4.76)	77.5	52.5	52.5	47.5	27.5	17.5	32.5	47.5	67.5	87.5
0548	(3.34)	87.5	57.5	47.5	52.5	27.5	22.5	27.5	47.5	57.5	77.5
0549	(6.09)	82.5	57.5	52.5	52.5	37.5	22.5	37.5	42.5	72.5	82.5
0550	(4.12)	82.5	62.5	52.5	47.5	27.5	22.5	37.5	47.5	67.5	77.5
Mean	(4.24)	81.5	57.5	50.5	49.5	30.5	22.5	33.5	45.5	63.5	75.5
S.D.	(1.26)	4.2	3.5	2.7	2.7	4.5	3.5	4.2	2.7	8.2	13.5
Animal	(Q-10 dB)					Post-Exposure					
0546	(4.79)	102.0*	92.5	92.5	87.5	72.5	87.5	77.5	82.5	92.5	92.0*
0547	(5.56)	102.0*	95.0*	95.0*	87.5	72.5	92.5	91.0*	94.0*	98.0*	92.0*
0548	(4.53)	82.5	62.5	57.5	62.5	47.5	32.5	37.5	62.5	72.5	92.5
0549	(8.78)	77.5	62.5	52.5	52.5	37.5	17.5	42.5	57.5	52.5	72.5
0550	(2.21)	72.5	57.5	52.5	42.5	22.5	22.5	22.5	37.5	42.5	67.5
Mean	(5.17)	87.3	74.0	70.0	66.5	50.5	50.5	54.2	66.8	71.6	83.3
S.D.	(2.37)	13.9	18.2	21.8	20.4	22.0	36.5	28.8	22.1	24.2	12.3

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 1/10M

Probe Frequency: 8.0 kHz

Masker (kHz):		0.450	1.300	2.500	5.900	7.000	8.100	9.300	11.000	12.700	14.000
Animal	(Q-10 dB)					Pre-Exposure					
0546	(1.07)	87.5	57.5	62.5	47.5	42.5	42.5	42.5	52.5	82.5	92.5
0547	(1.70)	87.5	62.5	62.5	42.5	37.5	37.5	52.5	62.5	92.5	95.0*
0548	(6.53)	77.5	67.5	52.5	42.5	42.5	17.5	32.5	52.5	67.5	95.0*
0549	(4.04)	82.5	72.5	67.5	52.5	52.5	47.5	37.5	52.5	77.5	95.0*
0550	(3.09)	82.5	57.5	57.5	37.5	37.5	27.5	32.5	57.5	97.5	95.0*
Mean	(3.29)	83.5	63.5	60.5	44.5	42.5	34.5	39.5	55.5	83.5	94.5
S.D.	(2.15)	4.2	6.5	5.7	5.7	6.1	12.0	8.4	4.5	11.9	1.1
Animal	(Q-10 dB)					Post-Exposure					
0546	(0.24)	102.0*	95.0*	91.0*	92.0*	98.0*	98.0*	94.0*	102.0*	100.0*	95.0*
0547	(0.83)	102.0*	95.0*	91.0*	87.5	92.5	98.0*	94.0*	102.0*	100.0*	95.0*
0548	(5.29)	92.5	72.5	72.5	57.5	62.5	47.5	62.5	77.5	100.0*	95.0*
0549	(0.83)	87.5	72.5	62.5	47.5	52.5	47.5	47.5	62.5	97.0*	95.0*
0550	(3.09)	87.5	62.5	62.5	47.5	47.5	37.5	42.5	67.5	100.0*	95.0*
Mean	(2.06)	94.3	79.5	75.9	66.4	70.6	65.7	68.1	82.3	99.4	95.0
S.D.	(2.11)	7.3	14.7	14.4	21.8	23.2	29.8	24.8	18.8	1.3	0.0

MASKED THRESHOLDS (dB SPL) Group: 160 dB 100X 1/10M

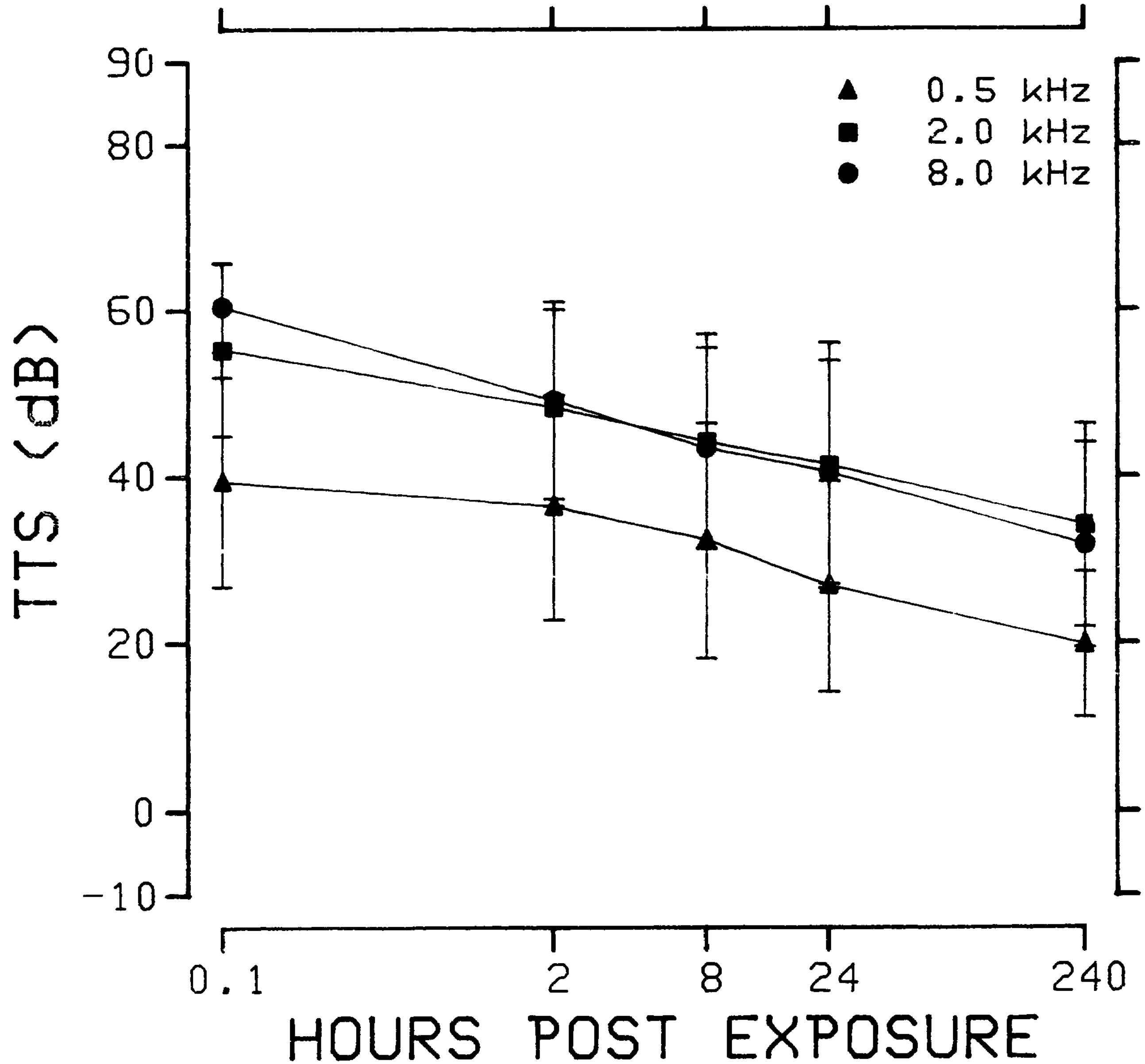
Probe Frequency: 11.2 kHz

Masker (kHz):		1.000	4.000	7.000	9.000	11.000	11.500	12.000	13.000	14.500	16.000
Animal	(Q-10 dB)					Pre-Exposure					
0546	(1.49)	57.5	42.5	32.5	32.5	27.5	27.5	27.5	42.5	47.5	62.5
0547	(4.87)	67.5	62.5	62.5	72.5	42.5	37.5	42.5	47.5	67.5	82.5
0548	(12.10)	82.5	67.5	77.5	67.5	42.5	42.5	32.5	52.5	72.5	87.5
0549	(4.40)	72.5	62.5	62.5	37.5	27.5	37.5	42.5	47.5	57.5	67.5
0550	(5.40)	67.5	62.5	57.5	52.5	22.5	27.5	27.5	42.5	57.5	77.5
Mean	(5.65)	69.5	59.5	58.5	52.5	32.5	34.5	34.5	46.5	60.5	75.5
S.D.	(3.91)	9.1	9.7	16.4	17.7	9.4	6.7	7.6	4.2	9.7	10.4
Animal	(Q-10 dB)					Post-Exposure					
0546	(*****)	99.0*	96.0*	98.0*	99.0*	102.0*	103.0*	102.0*	95.0*	102.0*	91.0*
0547	(*****)	99.0*	96.0*	98.0*	99.0*	102.0*	103.0*	97.5	95.0*	102.0*	91.0*
0548	(2.42)	82.5	62.5	67.5	47.5	42.5	42.5	42.5	52.5	72.5	77.5
0549	(11.48)	72.5	52.5	52.5	27.5	32.5	22.5	32.5	37.5	52.5	82.5
0550	(3.11)	67.5	62.5	57.5	47.5	27.5	32.5	32.5	32.5	47.5	67.5
Mean	(5.67)	84.1	73.9	74.7	64.1	61.3	60.7	61.4	62.5	75.3	81.9
S.D.	(5.04)	14.6	20.6	21.9	32.9	37.5	39.3	35.3	30.6	26.1	9.9

The Group Mean Recovery Curves

Measured at Three Test Frequencies

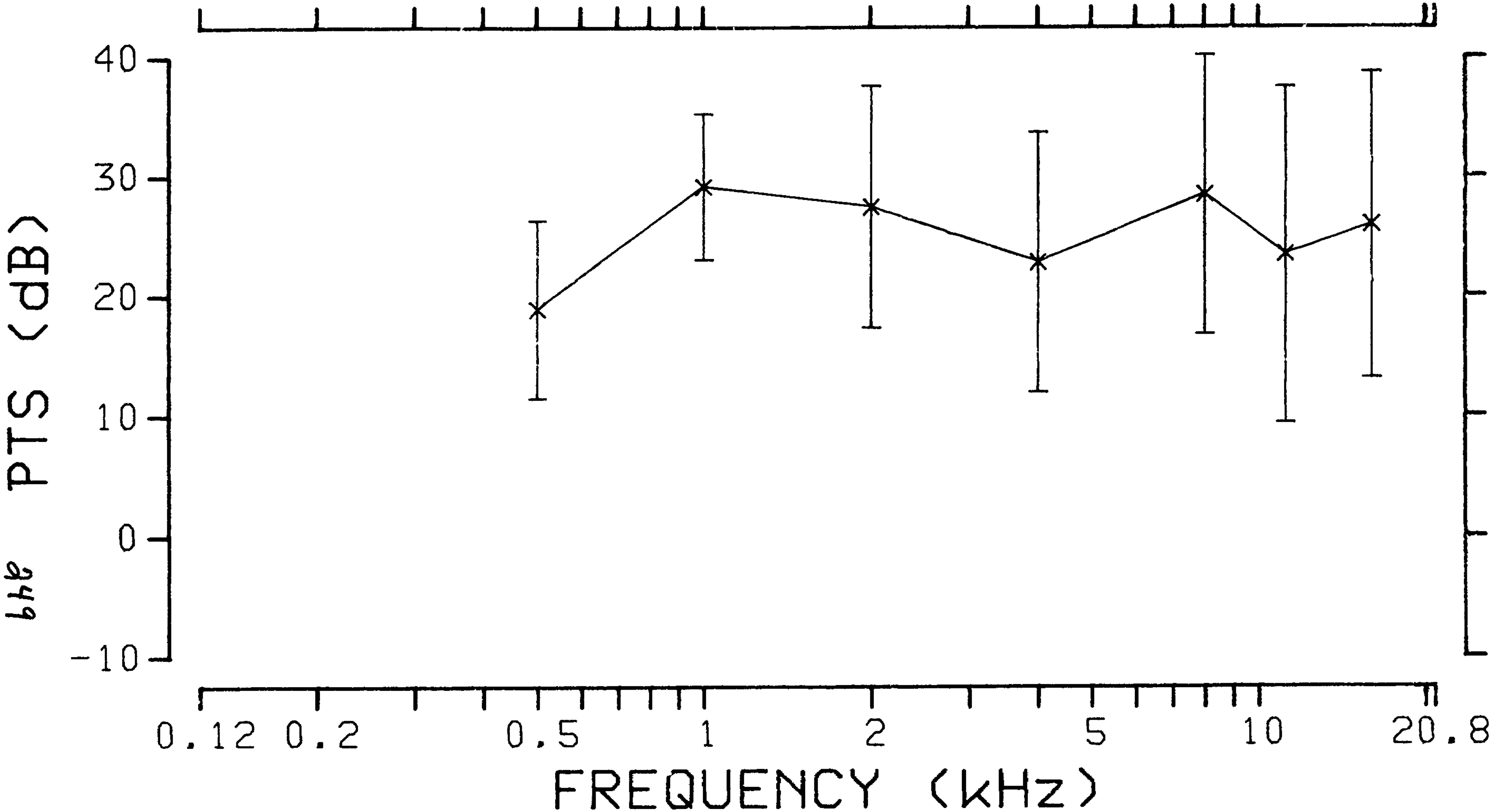
MEAN DATA (n=5) - 160 dB 100X 1/10M



The Group Mean Permanent Threshold Shift (PTS)

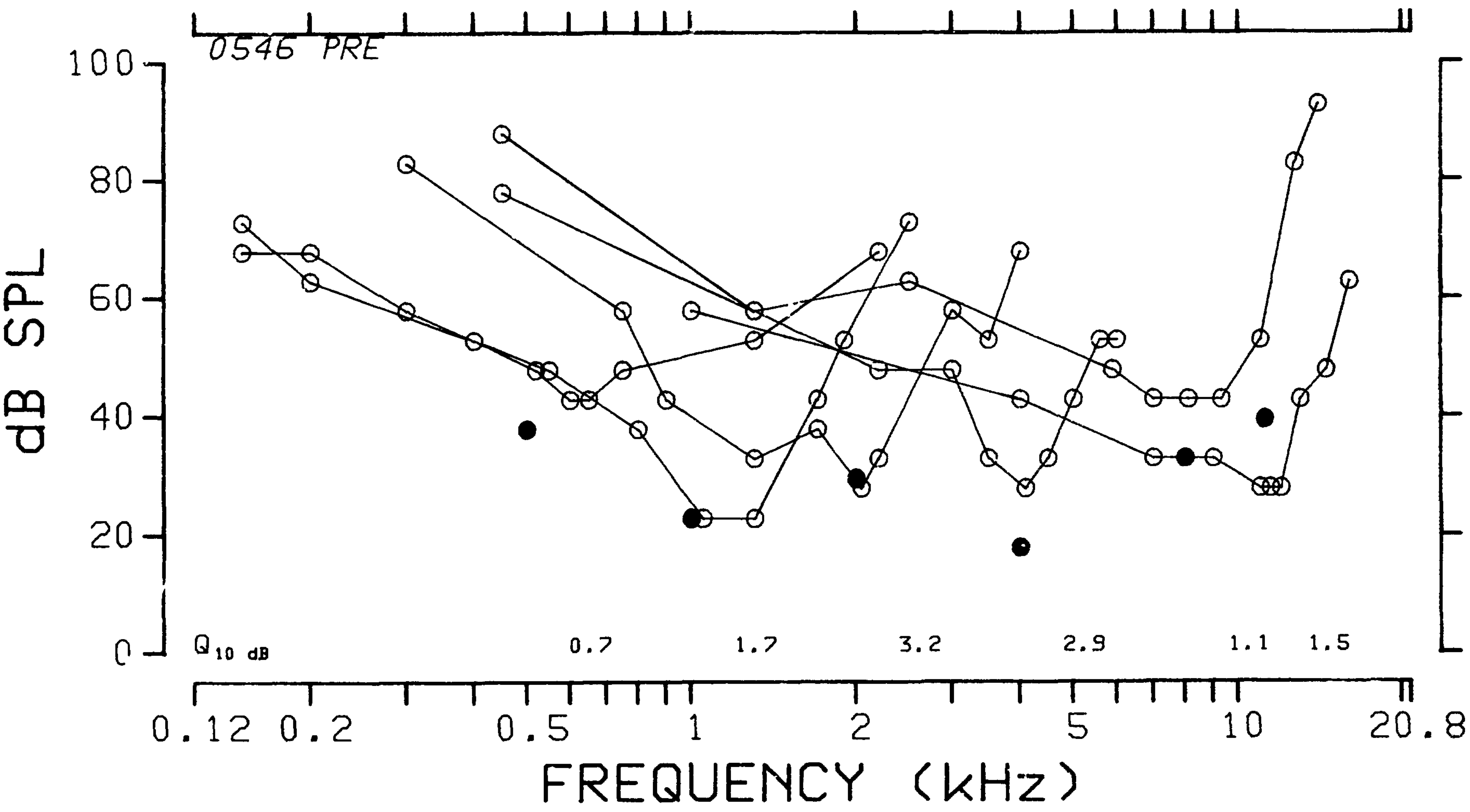
for all Test Frequencies

MEAN DATA (n=5) - 160 dB 100X 1/10M

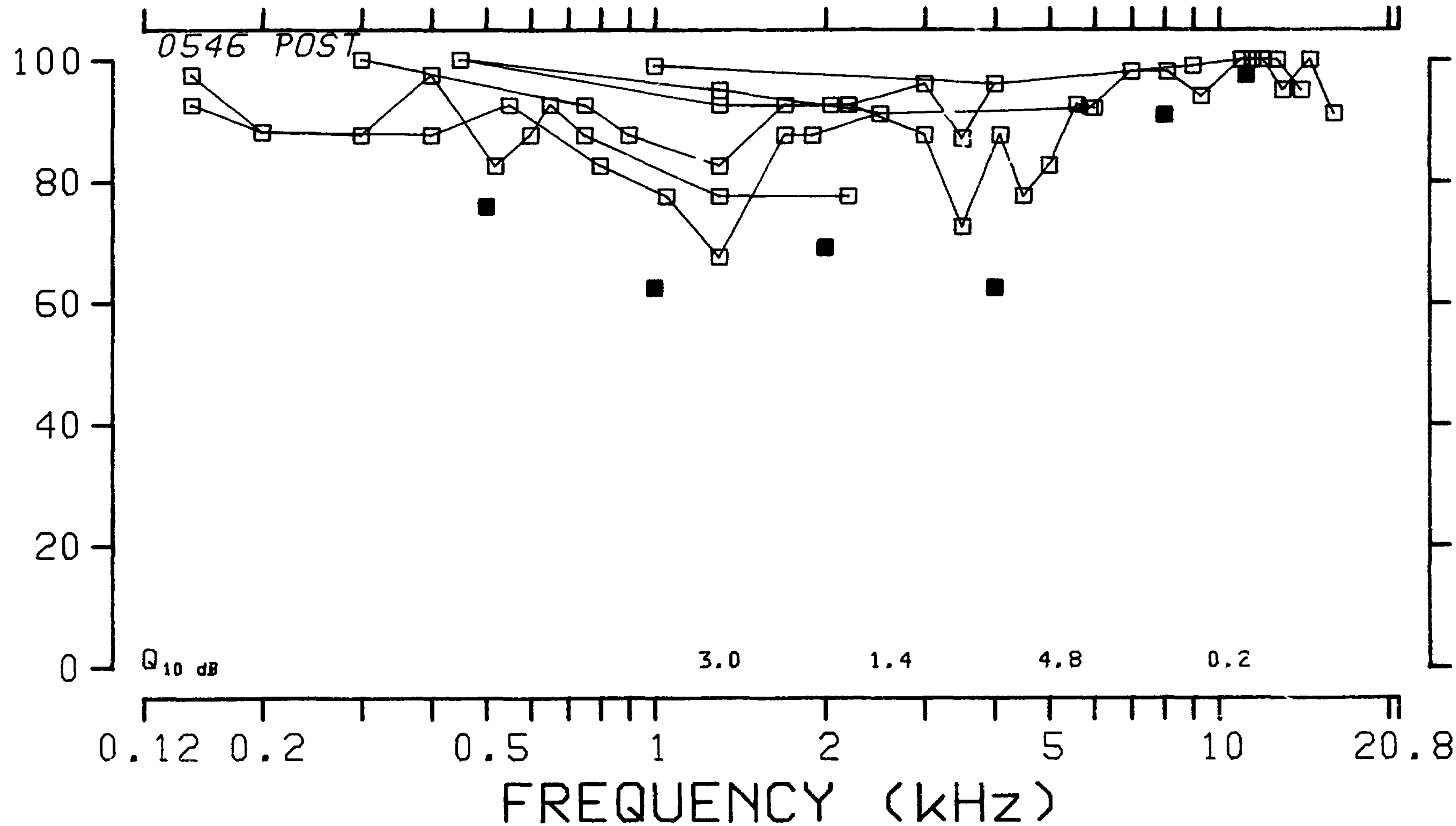


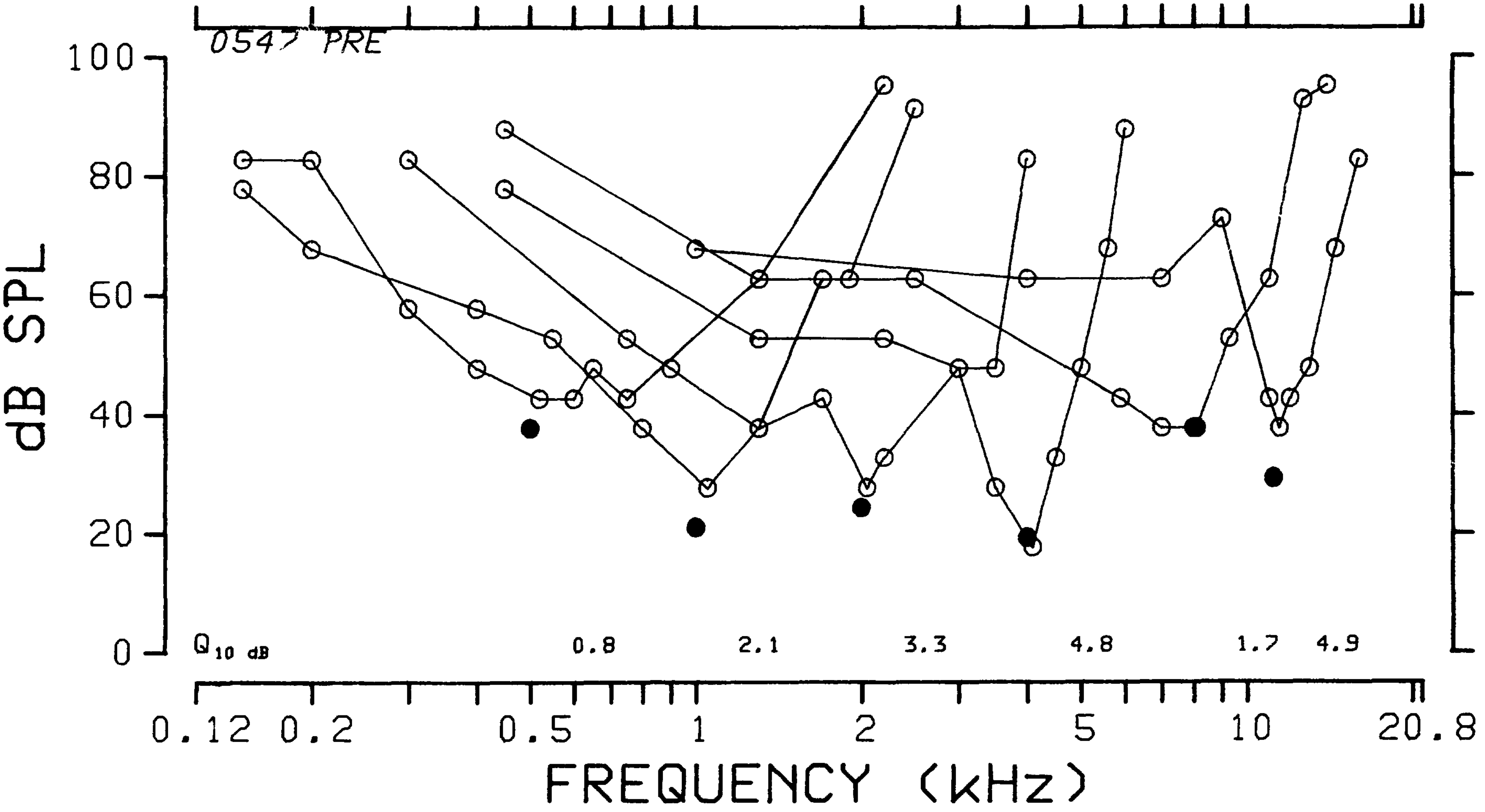
The Pre and Postexposure Tuning Curves for
Individual Animals in this Exposure Group.

The Solid Symbol represents the intensity of the probe tone.

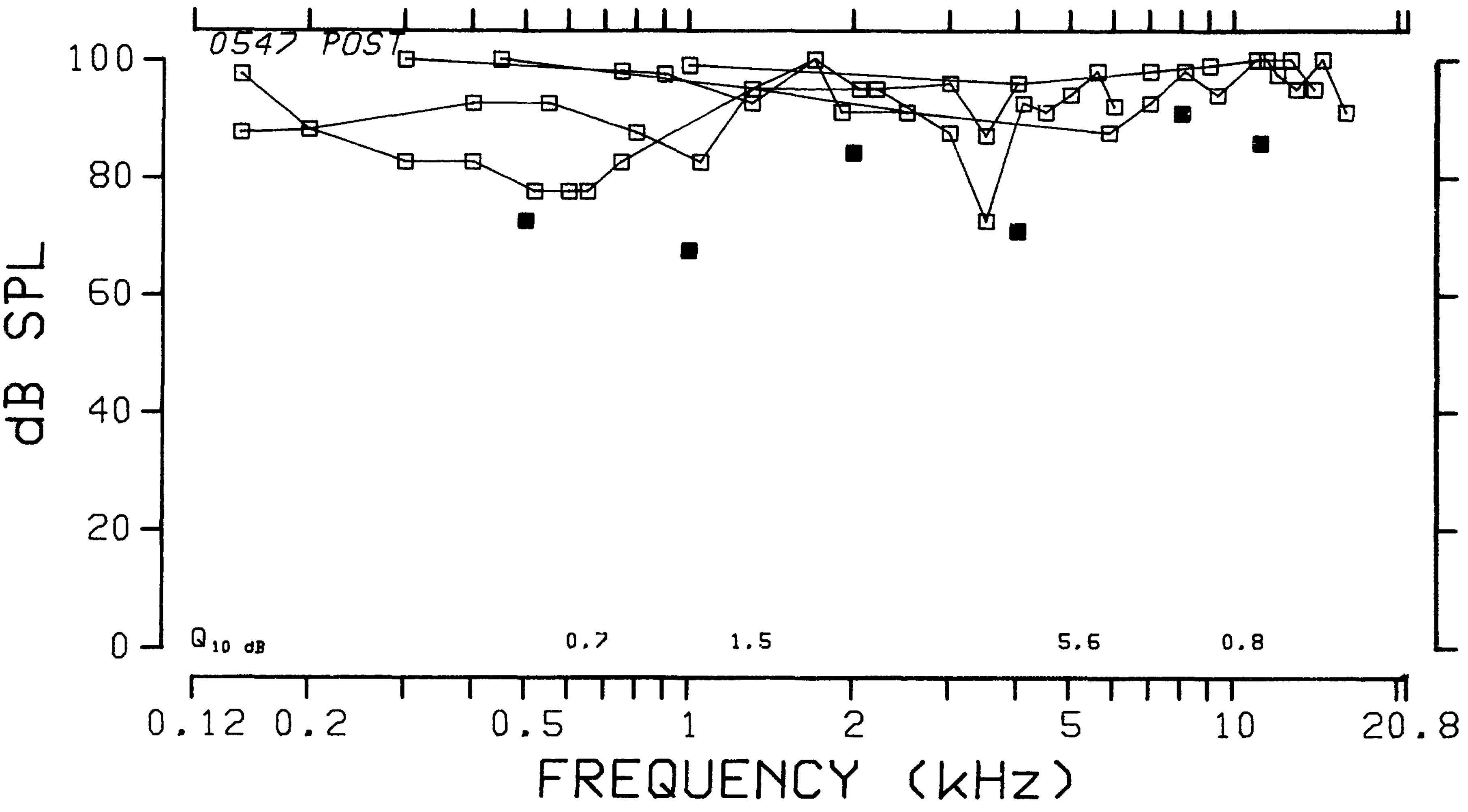

0546 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
0.7
1.7
3.2
2.9
1.1
1.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

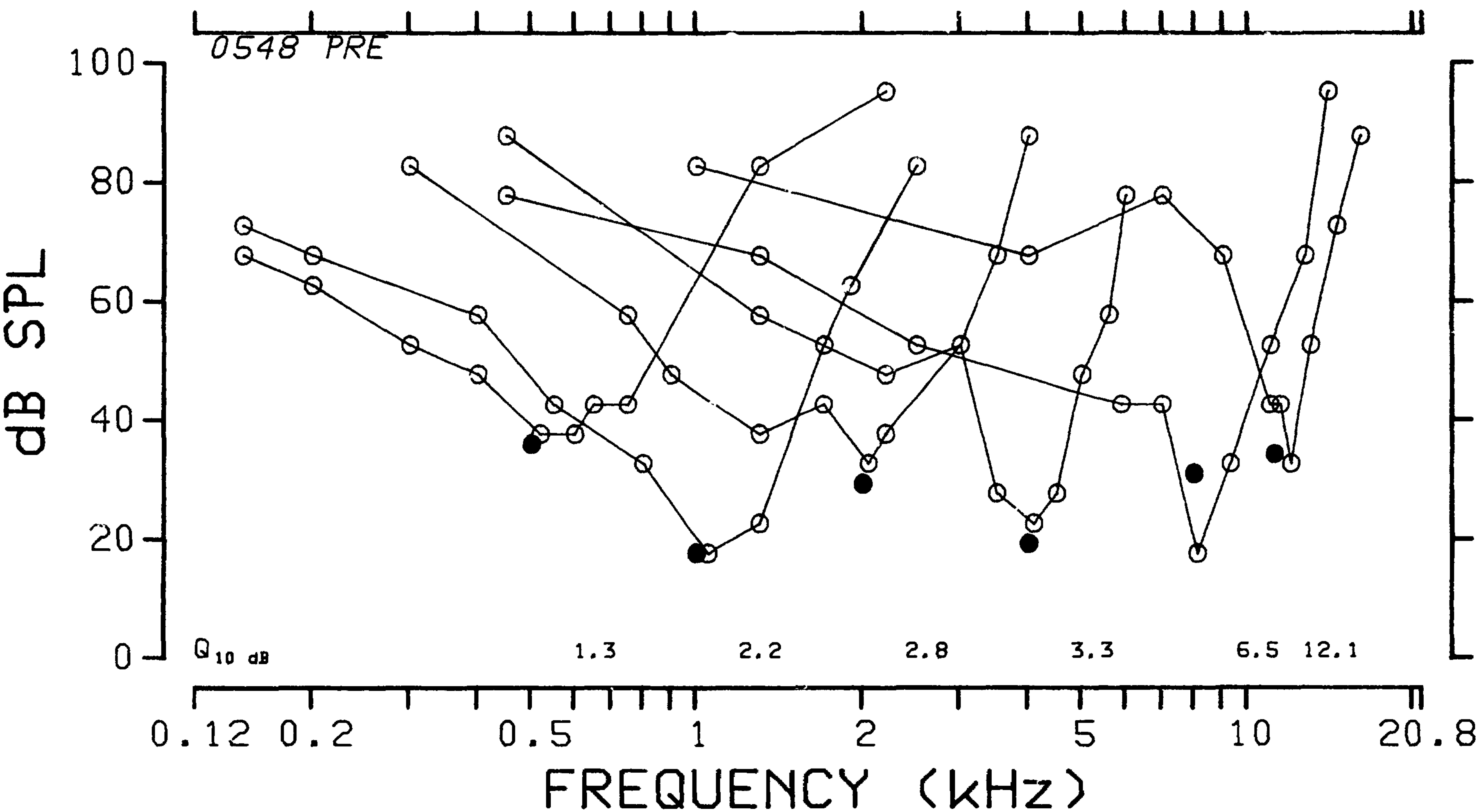
251


0546 POST
dB SPL
100
80
60
40
20
0
Q10 dB
3.0
1.4
4.8
0.2
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

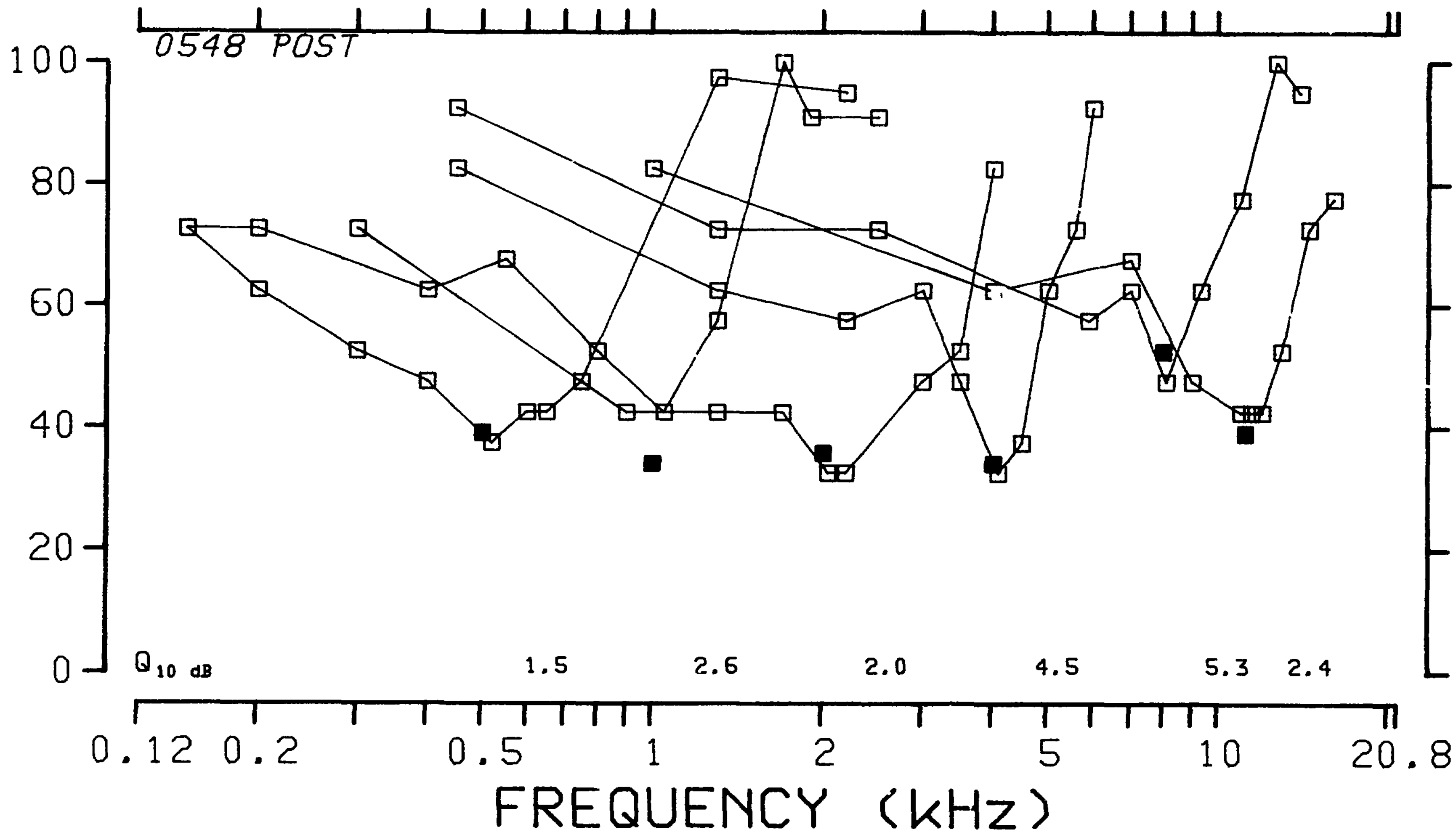


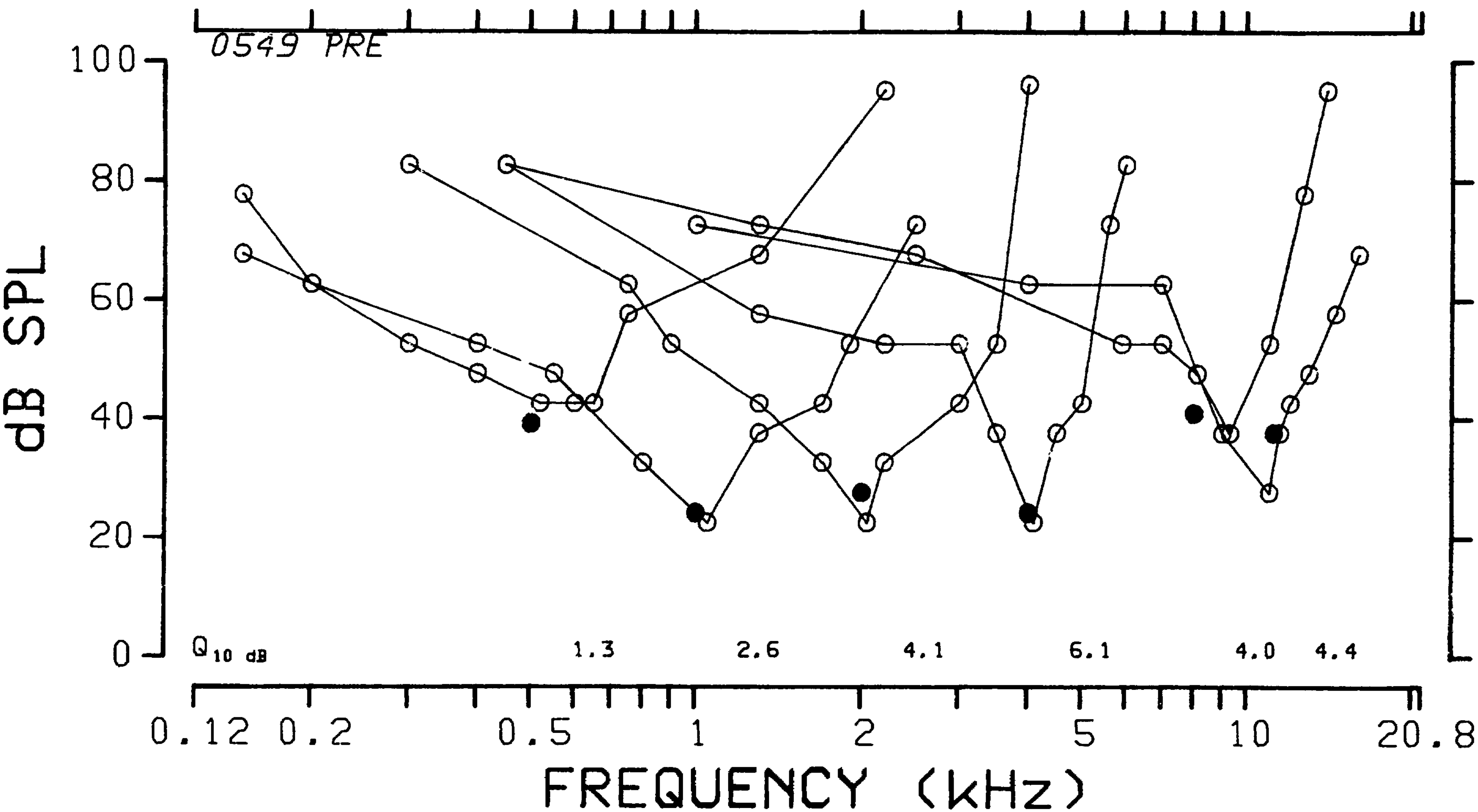
0547 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
0.8
2.1
3.3
4.8
1.7
4.9
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0547 POST
100
80
60
40
20
0
dB SPL
Q10 dB
0.7
1.5
5.6
0.8
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

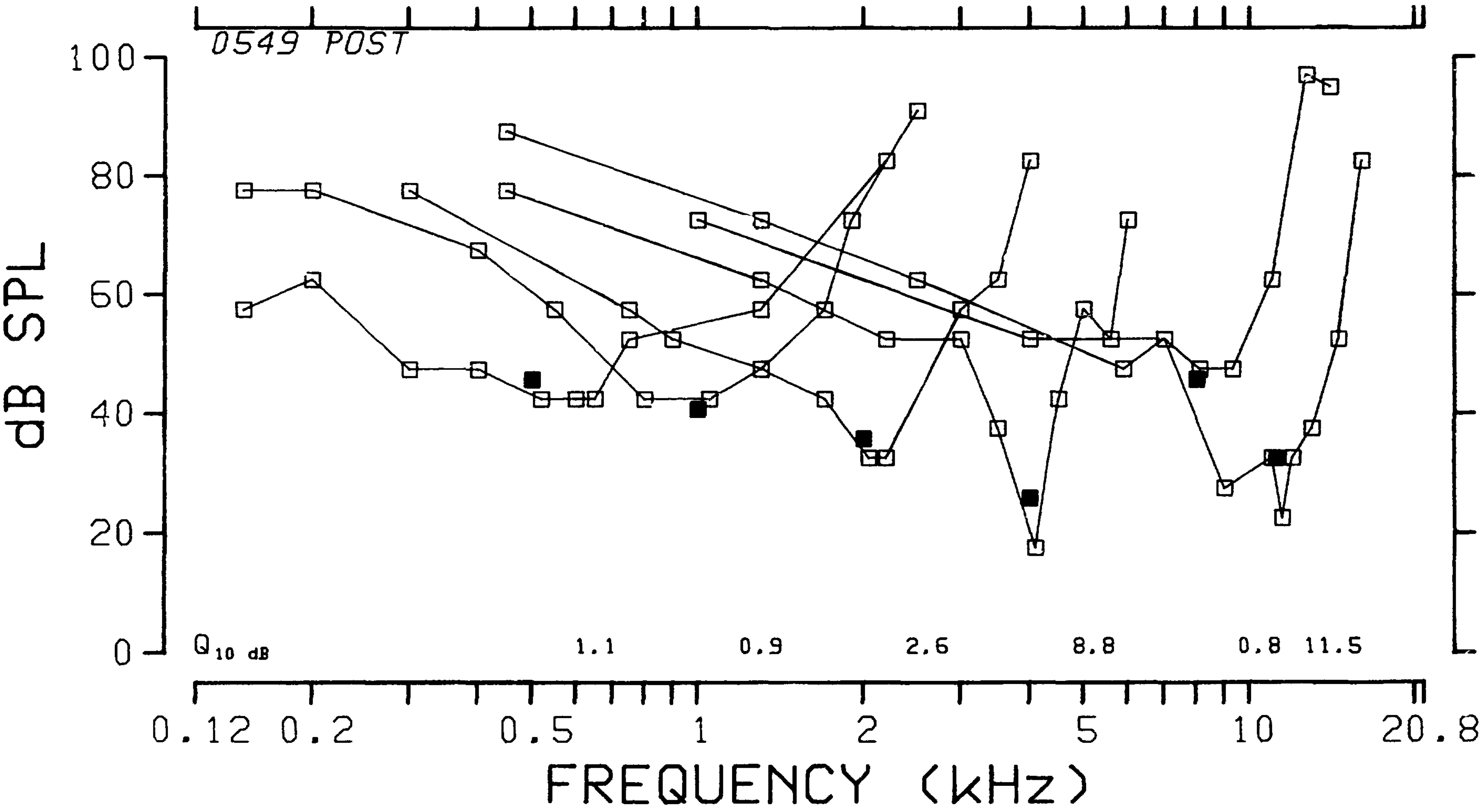

0548 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
1.3
2.2
2.8
3.3
6.5
12.1
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

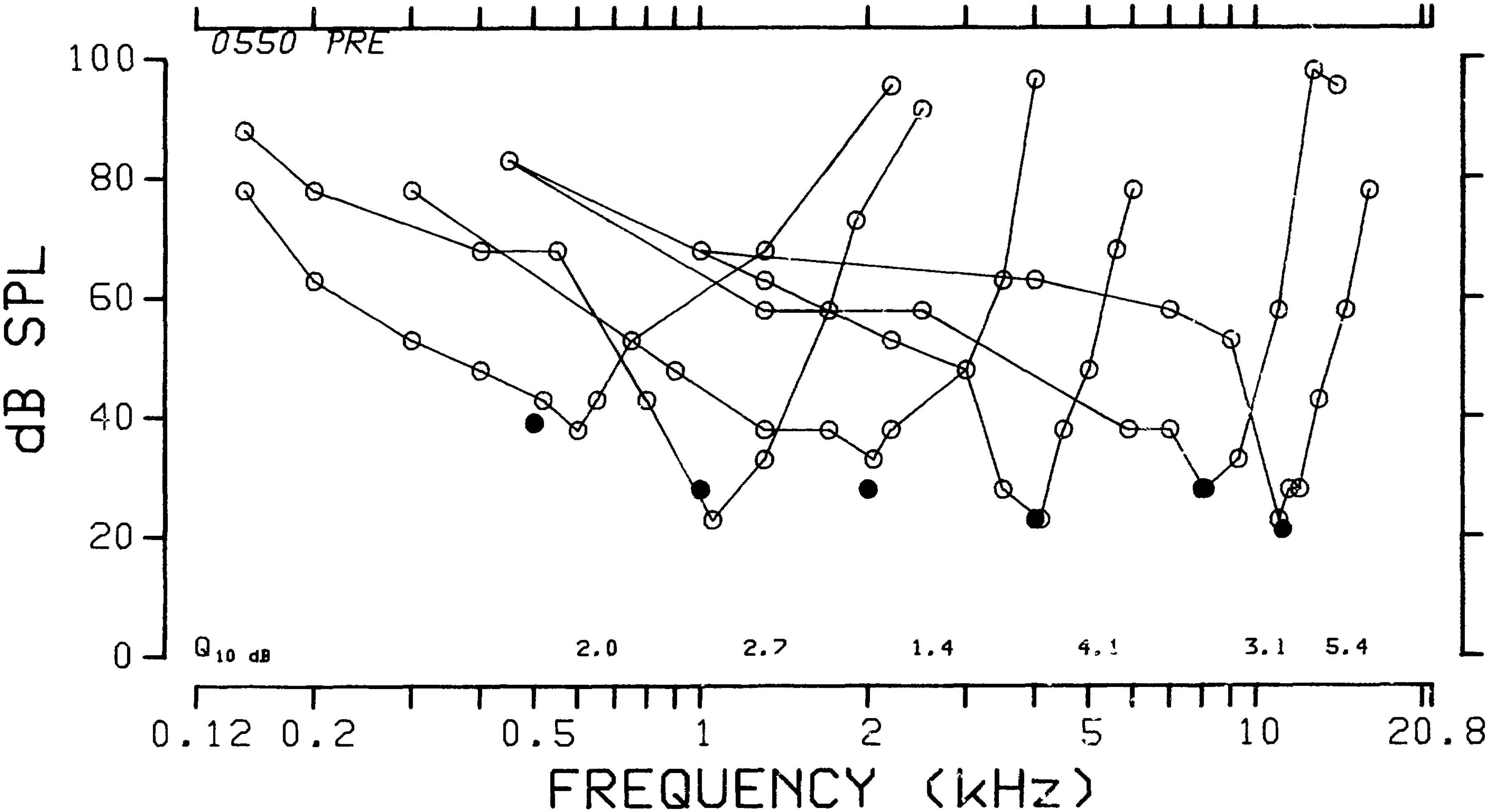
255

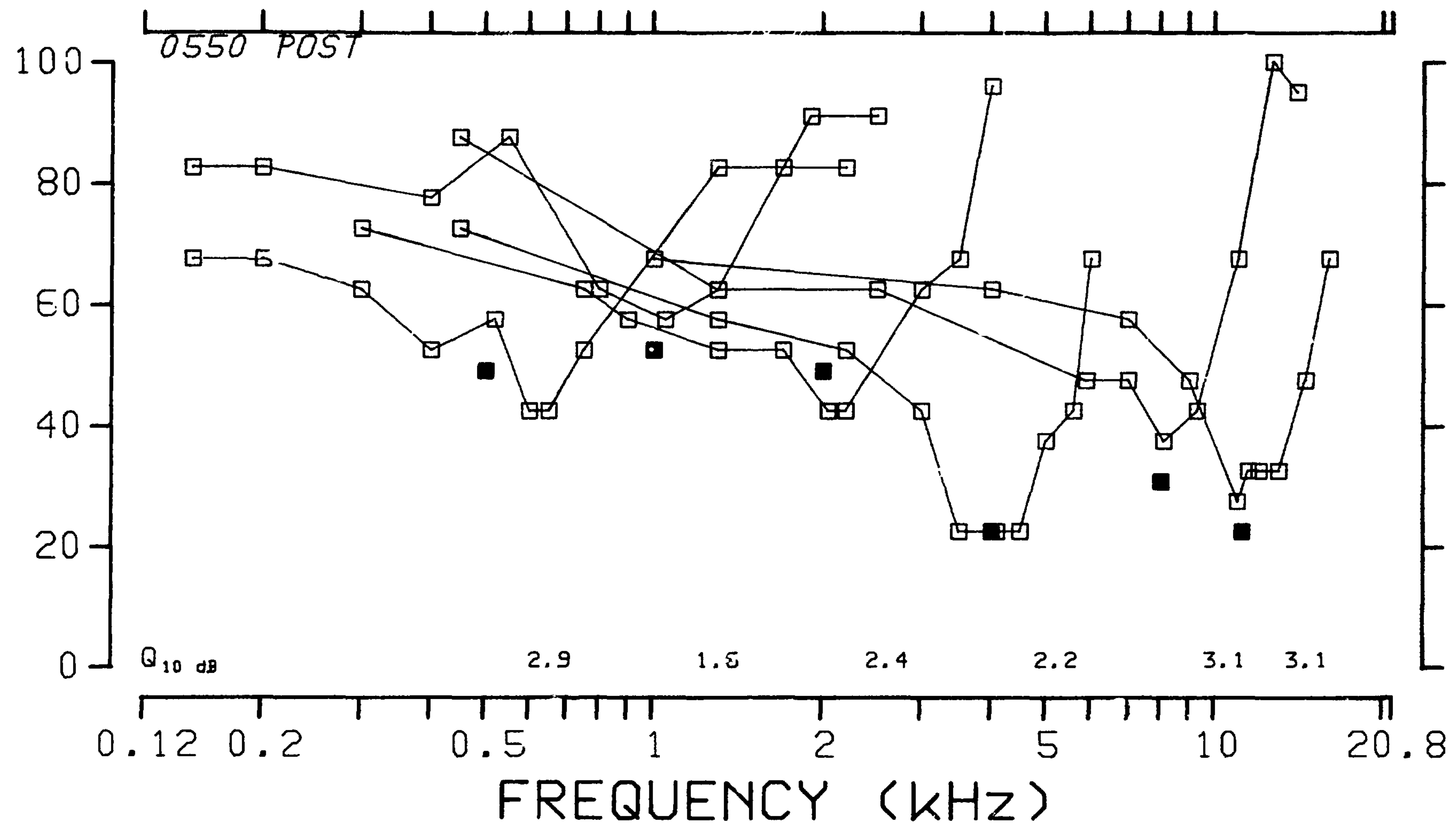

0548 POST
dB SPL
100
80
60
40
20
0
Q10 dB
1.5
2.6
2.0
4.5
5.3
2.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0549 PRE
dB SPL
100
80
60
40
20
0
Q10 dB
1.3
2.6
4.1
6.1
4.0
4.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

257


0549 POST
100
80
60
40
20
0
dB SPL
Q10 dB
1.1
0.9
2.6
8.8
0.8
11.5
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)


0550 PRE
dB SPL
100
80
60
40
20
0
$Q_{10\ dB}$
2.0
2.7
1.4
4.1
3.1
5.4
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)



0550 POST
dB SPL
100
80
60
40
20
0
Q10 dB
2.9
1.5
2.4
2.2
3.1
3.1
0.12
0.2
0.5
1
2
5
10
20.8
FREQUENCY (kHz)

260

160 dB 100X 1/10M

TOTAL NUMBER OF COCHLEAR SENSORY CELLS MISSING

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0546	507	2033	2059	1668	5760
0547	478	2001	1962	1615	5578
0548	0	60	59	185	304
0549	4	23	23	79	125
0550	16	144	61	79	284
GROUP MEAN	201				2410
S.D.	266				2976
S.E.	119				1331

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

	OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	OUTER HAIR CELLS
GROUP MEANS			
	0.125 kHz	11.2	55.8
	0.25 kHz	32.2	192.0
	0.5 kHz	6.2	284.0
	1 kHz	7.6	360.8
	2 kHz	17.4	386.0
	4 kHz	20.2	375.4
	8 kHz	44.2	413.2
	16 kHz	62.0	343.0
STANDARD DEVIATIONS			
	0.125 kHz	14.2	42.4
	0.25 kHz	52.4	253.4
	0.5 kHz	9.7	366.7
	1 kHz	10.5	437.3
	2 kHz	27.2	486.9
	4 kHz	27.0	504.2
	8 kHz	59.5	477.4
	16 kHz	99.5	450.1

160 dB 100X 1/10M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0546							
0.125 kHz	30	43	32	31	106	1	5
0.25 kHz	121	259	282	65	606	6	7
0.5 kHz	23	292	300	139	731	16	44
1 kHz	25	289	290	283	862	7	55
2 kHz	62	297	293	289	879	60	98
4 kHz	44	297	297	297	891	31	102
8 kHz	122	297	297	297	891	150	185
16 kHz	80	259	268	267	794	74	114
TOTALS	507	2033	2059	1668	5760	345	610
CHINCHILLA 0547							
0.125 kHz	23	16	27	55	98	2	5
0.25 kHz	39	140	53	74	267	1	0
0.5 kHz	2	274	312	51	637	1	5
1 kHz	10	315	313	187	815	6	39
2 kHz	25	321	322	313	956	31	77
4 kHz	55	321	321	321	963	73	128
8 kHz	95	322	322	322	966	157	140
16 kHz	229	292	292	292	876	358	273
TOTALS	478	2001	1962	1615	5578	629	667
CHINCHILLA 0548							
0.125 kHz	0	4	3	17	24	0	0
0.25 kHz	0	1	3	30	34	0	0
0.5 kHz	0	3	4	8	15	0	0
1 kHz	0	2	3	5	10	0	0
2 kHz	0	2	0	3	5	0	0
4 kHz	0	1	0	1	2	0	0
8 kHz	0	43	40	112	195	0	6
16 kHz	0	4	6	9	19	0	0
TOTALS	0	60	59	185	304	0	6

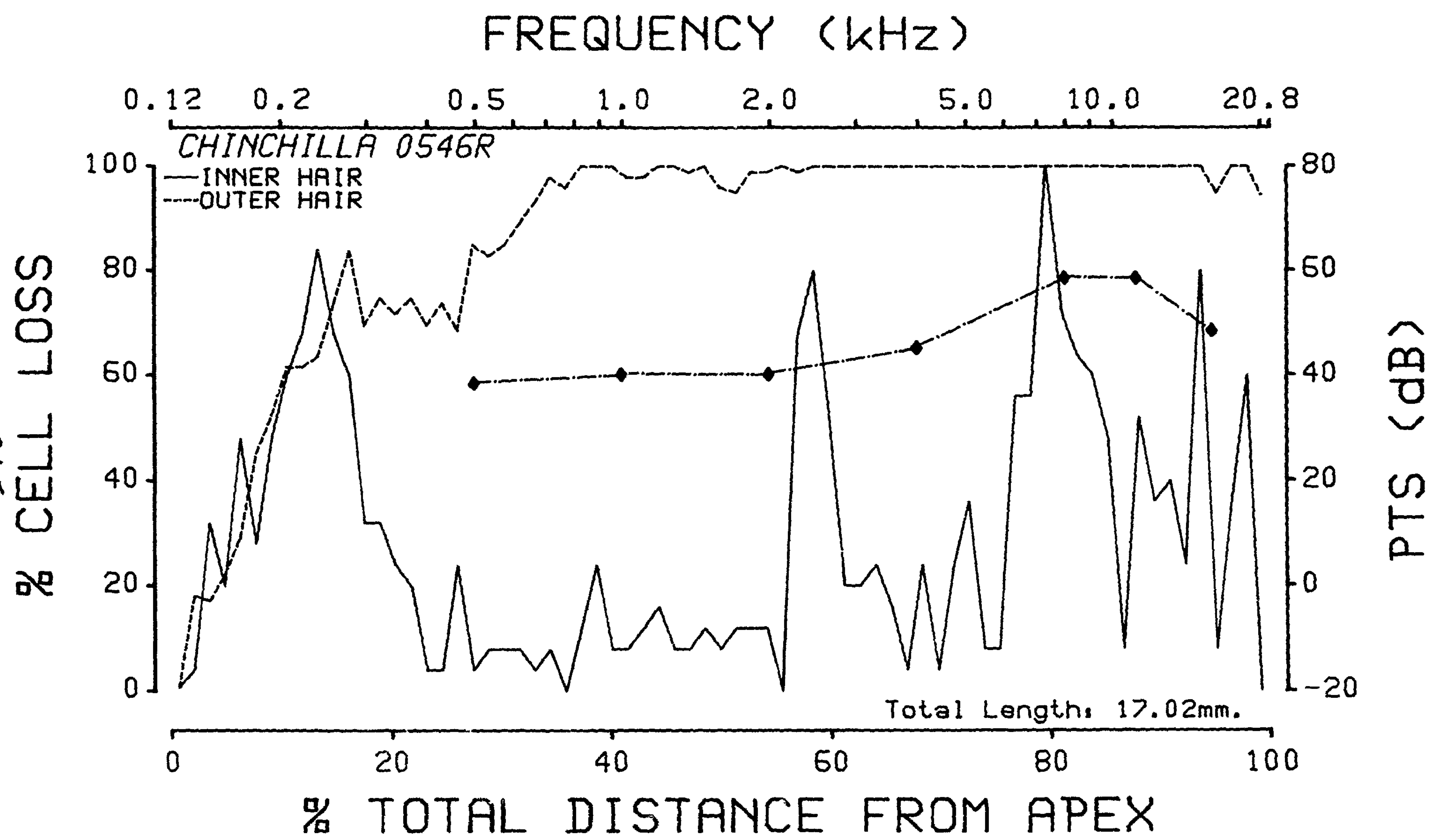
160 dB 100X 1/10M

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND FREQUENCIES

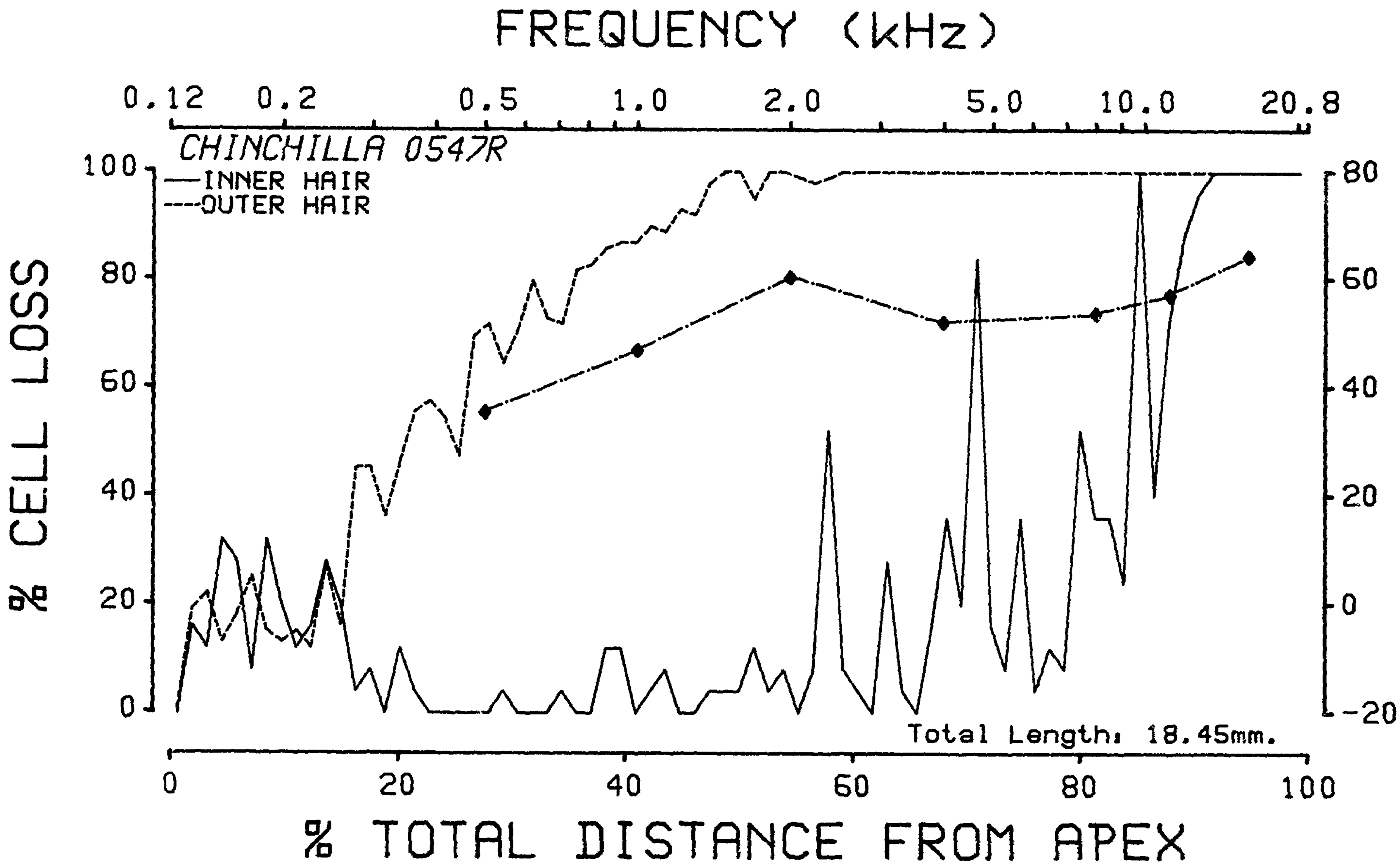
	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	comb. OUTER HAIR CELLS	INNER PILLAR CELLS	OUTER PILLAR CELLS
CHINCHILLA 0549							
0.125 kHz	0	0	7	23	30	0	1
0.25 kHz	0	2	0	19	21	1	0
0.5 kHz	0	5	2	9	16	0	0
1 kHz	2	14	6	9	29	0	6
2 kHz	0	0	0	8	8	0	0
4 kHz	1	1	2	6	9	0	0
8 kHz	1	0	2	3	5	0	0
16 kHz	0	1	4	2	7	0	0
TOTALS	4	23	23	79	125	1	7
CHINCHILLA 0550							
0.125 kHz	3	3	7	11	21	0	1
0.25 kHz	1	4	8	20	32	1	1
0.5 kHz	6	7	4	10	21	1	1
1 kHz	1	62	14	12	88	0	0
2 kHz	0	47	1[illegible]	16	82	0	1
4 kHz	1	6	3	3	12	0	0
8 kHz	3	6	[illegible]	3	9	1	0
16 kHz	1	9	6	4	19	0	3
TOTALS	16	144	61	79	284	3	7
GROUP MEANS							
0.125 kHz	11.2	13.2	15.2	27.4	55.8	0.6	2.4
0.25 kHz	32.2	81.2	69.2	41.6	192.0	1.8	1.6
0.5 kHz	6.2	116.2	124.4	43.4	284.0	3.6	10.0
1 kHz	7.6	136.4	125.2	99.2	360.8	2.6	20.0
2 kHz	17.4	133.4	126.8	125.8	386.0	18.2	35.2
4 kHz	20.2	125.2	124.6	125.6	375.4	20.8	46.0
8 kHz	44.2	133.6	132.2	147.4	413.2	61.6	66.2
16 kHz	62.0	113.0	115.2	114.8	343.0	86.4	78.0
TOTALS	201.0	852.2	632.8	725.2	2410.2	195.6	259.4

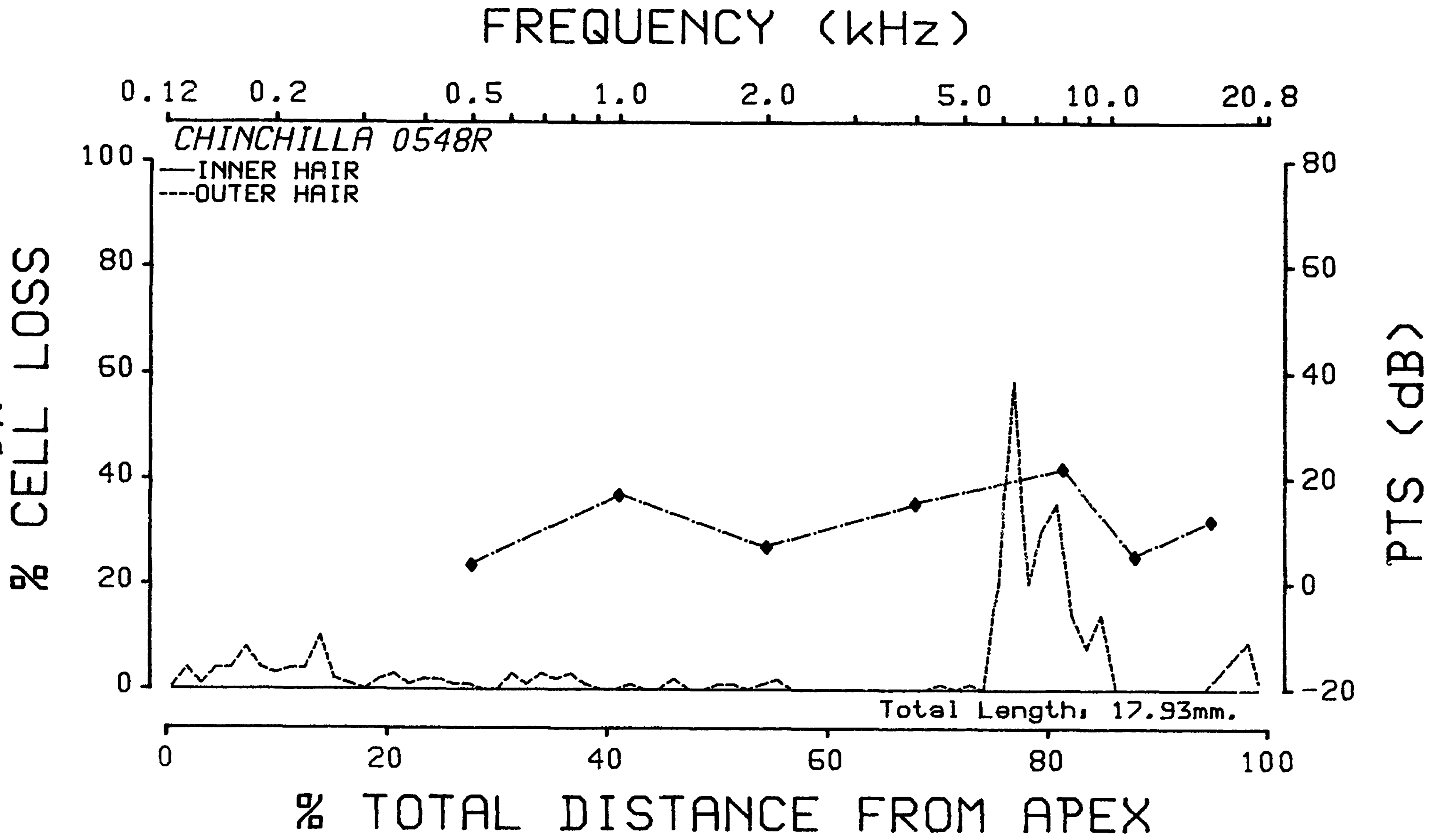
Cochleograms and PTS Audiograms

for Individual Animals

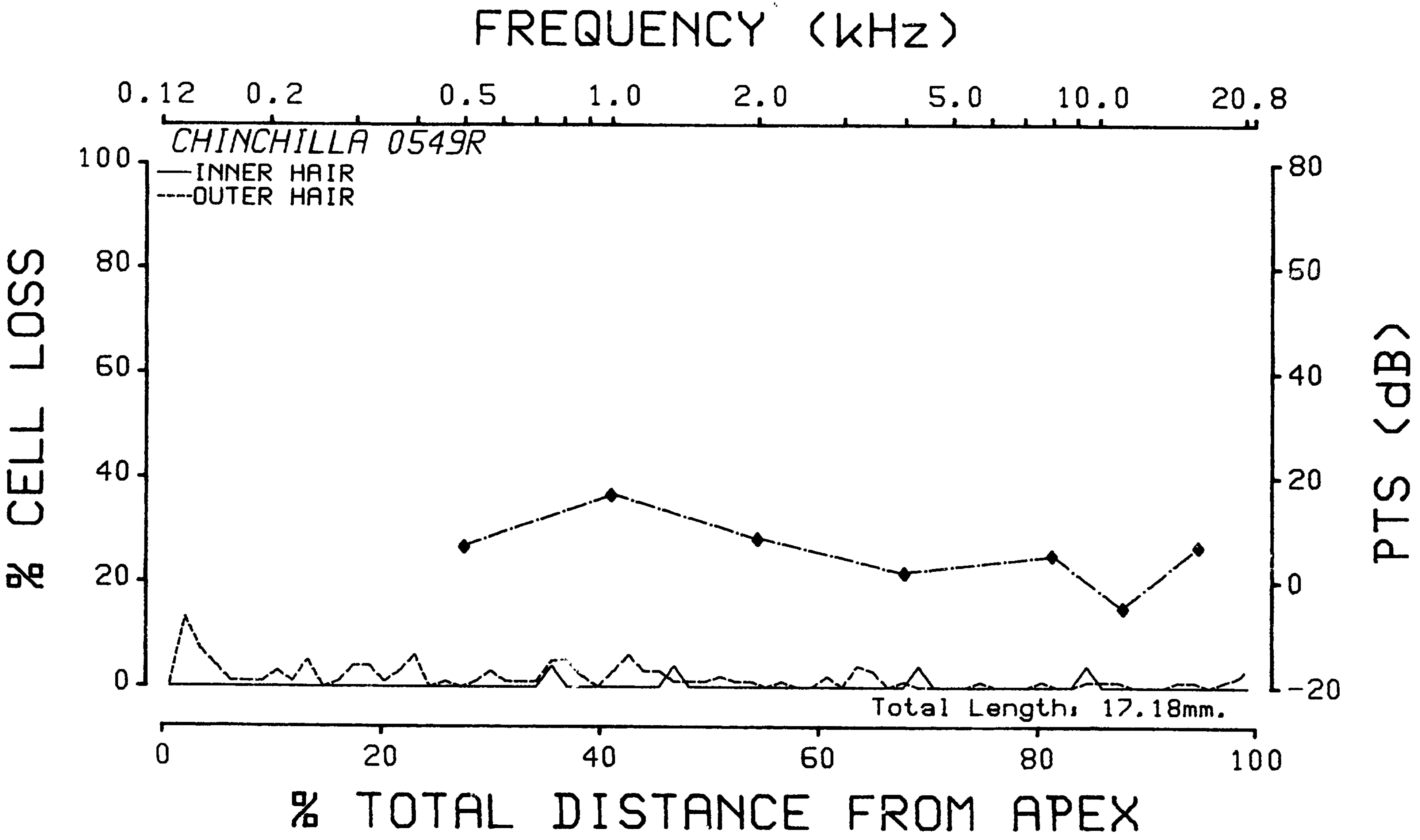

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0546R
INNER HAIR
OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.02mm.
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100

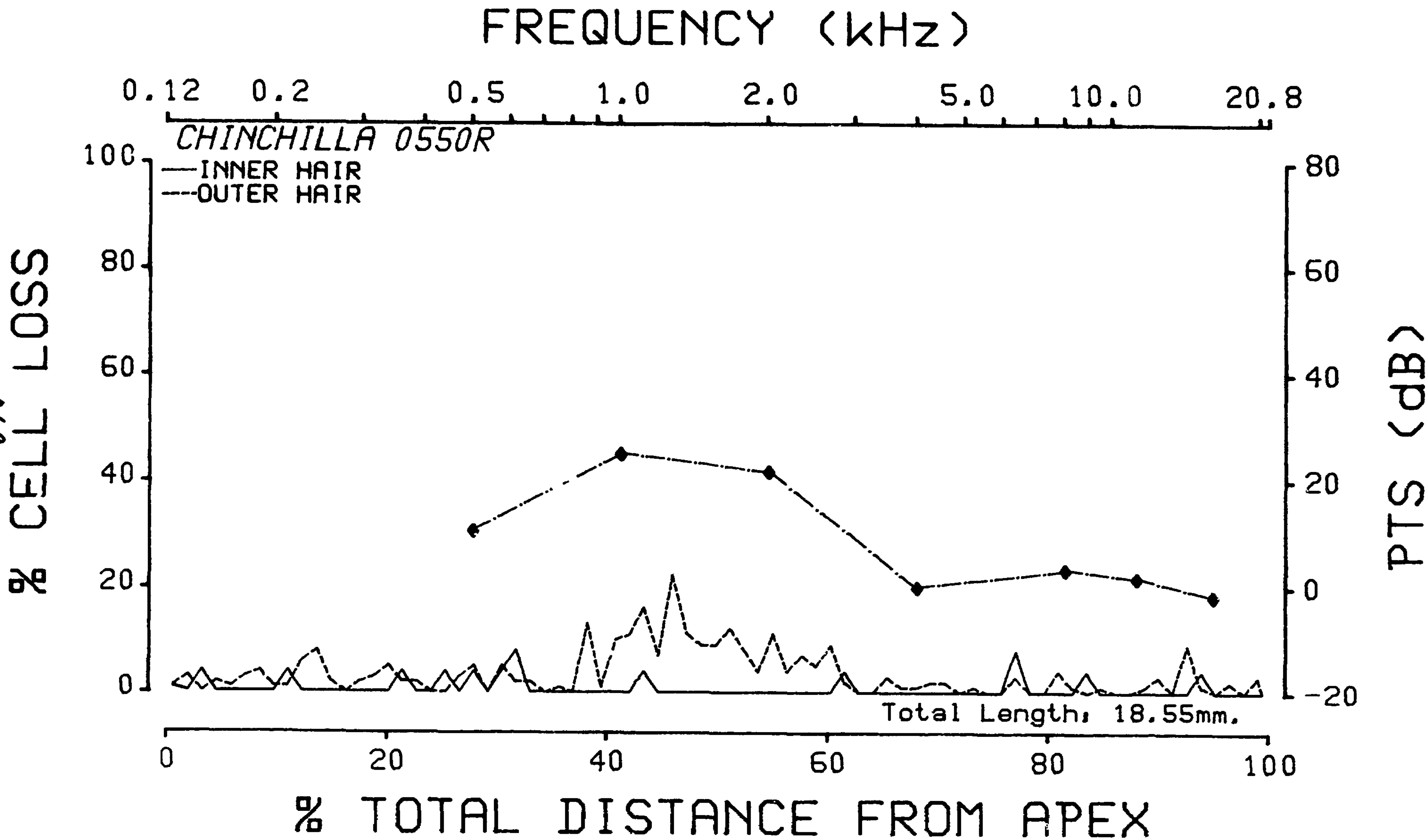
265


FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
CHINCHILLA 0547R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100 80 60 40 20 0
PTS (dB)
80 60 40 20 0 -20
Total Length: 18.45mm.
0 20 40 60 80 100
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0548R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 17.93mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0549R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
50
40
20
0
-20
Total Length: 17.18mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA 0550R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Total Length: 18.55mm.
% TOTAL DISTANCE FROM APEX

Appendix II

State University of New York at Plattsburgh
Auditory Research Laboratories

Report No. 88-2

The Effects of Blast Trauma (Impulse Noise) on Hearing: A Parametric Study

FOREWORD

Disclaimer

Citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

Animal Use

In conducting the research described in this report, the investigators adhered to the "Guide for the Care and use of Laboratory Animals," prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council (DHHS Publication No. (NIH) 86-23, revised 1985).

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ABSTRACT

There are three broad goals to this project. The first and primary goal is to begin the systematic development of a data base from which one could estimate the hazards to hearing resulting from exposure to blast waves or other high level impulse noise transients. To achieve this primary objective the following two objectives must first be achieved: (1) to develop a methodology to efficiently acquire data on a large number of experimental animals that have been exposed to a variety of blast wave configurations. This includes audiometric, histological and acoustic variables; (2) to develop a set of blast wave simulation devices which can reliably generate blast waves with a variable distribution of spectral energy in a laboratory environment. This report will describe progress that was achieved on each of these objectives. During this first year data acquisition was completed on 109 chinchillas that were exposed to one of a series of very low frequency (125 Hz) energy-content blast wave exposure paradigms. This data represents the first of four phases of a parametric study that was designed to estimate the contributions of individual blast wave exposure variables on the production of hearing loss. Hearing function was measured using the auditory evoked potential (AEP) technique. The evaluation of hearing consisted of pre- and postexposure measurements of pure tone thresholds and tuning curves (masked thresholds). Quantitative and qualitative data on each experimental cochlea was obtained from the traditional surface preparation technique. The objective of this approach was to correlate the exposure variables with functional and morphological indices of trauma. The blast waves used in this first study were generated using a conventional compressed air-driven shock tube. The following blast wave parameters were studied:

1. Intensity of the blast wave. The intensity was characterized by the peak sound pressure level of the initial positive over pressure, and by the total energy (J/m^2) of the exposure. Three intensities were used; 150, 155, and 160 dB peak SPL.

2. Inter-stimulus interval (ISI) i.e. the effects of repetition rate. Rates of 1/m, 10/m, and 1/10m were used.

3. Total number of impulses (N), where N = 1, 10 and 100.

The following preliminary conclusions can be made from these data: (1) There was no statistical difference in the amount of hearing loss or the amount of sensory cell loss for exposure to a single impulse at 150, 155, or 160 dB peak SPL. Individual animals showed no permanent hearing loss and no significant sensory cell loss. (2) There is a considerable amount of variability or degree of susceptibility across animals as the severity of the exposure increases. This increase in susceptibility seems to be tied more to peak levels of the stimulus than it is to the total energy. The variability produces, in the extreme cases, a complete dichotomy in the results (e.g. see the 160 dB, 100X, 1/10m data) that makes it difficult to describe the data with conventional statistics. The only alternative seems to be to substantially increase the total number of animals in such exposure conditions. (3) With the above in mind, a general, though not surprising trend in the data is that as the peak levels and the N increase permanent effects increase; these permanent effects seem to be dependent upon peak levels more than upon the total energy in the exposure stimulus. Also, for a constant peak and energy level, the more rapid presentation rate (10/min) produces the greater effect although the effect is not consistent.

I. INTRODUCTION

Blast waves, resulting from the sudden release of energy into the atmosphere (e.g., gun fire, cannon discharge, etc.), are one of the primary sources of high level impulse noise exposure in the military. These noise impulses are brief acoustic transients which have a very high intensity (often in excess of 180 dB peak SPL) and a relatively broad distribution of energy in the audible frequency spectrum. The blast waves that are typically encountered in military environments constitute a serious health hazard because of their damaging effects on hearing and other organ systems of the body. With a continuing increase in the sophistication and power of weapon systems, there has been a concomitant increase in the peak noise levels to which personnel are exposed. While there exists a body of knowledge on the effects of continuous noise exposure on hearing, as well as to some extent the effects of impact noise on hearing, there is very little literature on the effects of blast wave and impulse noise exposure on hearing function. The paucity of data is due, in part, to the difficulty of producing well-controlled blast waves in a laboratory setting, and, in part, because of the inherent difficulties associated with animal research. Direct laboratory studies on humans are usually not possible because of the excessive noise levels that must be used.

There are no current, reliable guidelines for predicting the adverse effects of blast wave exposures on hearing. What is needed before any predictive schemes can be developed, is a data base resulting from parametric studies of blast waves and their effects on hearing function. Because of the comparative delicacy of the cochlea and its associated conductive mechanism, such a data base may also be useful in providing an early indication of impending blast-induced trauma to other systems of the body.

II. BACKGROUND

The following paragraphs provide some background information which highlights the existing body of knowledge on impulse noise effects. The first section deals briefly with some of the fundamental differences between impulse and continuous noise. Later sections describe some of the relations between the acoustic parameters of the impulse noise exposure and the magnitude of hearing loss. These introductory comments are intended only to focus attention on studies that bear a direct relation to the data of this report and are not intended as a comprehensive review of the subject. The reader should keep in mind that many of the issues and relations that are discussed are poorly understood and tenuous at best, since they are based upon very limited data.

A. Impulse versus Continuous Noise: There is a temptation to view the mechanisms of impulse* noise trauma as being essentially the same as those of continuous noise. Recent data, however, clearly differentiates impulse noise from other forms of noise. In the first instance, blast waves are different in a physical sense from tone bursts or noise impacts. They are characterized by a very rapid rise time (i.e., on the order of a microsecond or less) as a consequence of the shock front leading the pressure wave, and they obey an entirely different set of physical

---

* Impulse noise is being used here as a generic term to include both impact noise and blast waves (Friedlander waves). The former, usually being associated with industrial environments, is caused by the impact of two objects; while the latter are, of necessity, very intense (> 140 dB), and usually caused by the non-linear processes of shock wave propagation following an explosive discharge.

principles than conventional acoustic auditory stimuli. In addition, the waveforms contain a large amount of acoustic energy that is almost instantaneously applied to the conductive and sensory structures of the ear. Such an impulsive loading greatly increases the mechanical stresses that the peripheral auditory system must endure, and often results in mechanical damage to not only the middle ear structures, but to the delicate sensory structures of the inner ear as well. Thus, a basic difference between impulse and continuous noise is that in the former case we are dealing with a stimulus that can cause significant mechanical damage in the cochlea (Hamernik et al., 1984a), while in the latter case the stimulus, at levels normally encountered, causes damage primarily through metabolic effects. Comparatively little is known about the physiological effects of mechanical disruption of the membranous labyrinth and the ensuing intermixing of endolymph and perilymph (Hamernik et al., 1984b). In general, however, both mechanisms, mechanical and metabolic, are always active to some extent. Spoendlin (1976) has suggested that at intensities around 125 dB, direct mechanical destruction and metabolic exhaustion are competing mechanisms in cochlear pathologies.

Bohne (1974) has shown that a fracture of the reticular lamina leads to an intermixing of endolymph and perilymph producing a potassium rich milieu for the sensory cells. This mixing of cochlear fluids leads to the ultimate demise of the hair cells and to changes in the nerve fibers innervating the organ of Corti. The effects on more central structures, such as spiral ganglion cells and the central auditory pathways, have not been extensively studied (Morest, 1982). Recently Hamernik et al. (1984b) have shown that following a severe mechanically-induced lesion in the organ of Corti caused by blast exposure, the cells of the inner sulcus become extremely active. These cells begin to develop an unusual system of pseudopodia and villi. How these and other changes relate to recovery processes or to alterations of psychoacoustic hearing performance is not known.

Audiologically, the results of impulse noise exposure have also been atypical. Luz and Hodge (1971) have reported that for chinchilla, monkey, and human, the threshold recovery curve following exposure to reverberant impulses is non-monotonic, i.e., there is an initial fast recovery, a rebound to higher levels of temporary threshold shift (TTS), such that the maximum TTS may occur several hours after the impulse noise exposure. This second peak in the TTS function is followed by a slower recovery that is approximately linear in log time. This non-monotonic pattern is distinctly different from the "classic" linear-in-log-time recovery pattern that typically results from lower level continuous noise exposure in humans. The same type of non-linear recovery has been found in the chinchilla after an impulse noise exposure (Henderson et al., 1974; Patterson et al., 1985, 1986b; Hamernik et al., 1988). Furthermore, the data of Hamernik et al., (1988) indicates that this complex recovery pattern is frequently associated with a developing cochlear lesion. The practical consequence of the non-monotonic recovery following impulse noise exposure is that a single measurement of threshold shift (TS) during the early postexposure period is probably not a good index of acoustic trauma from high-level impulse noise. Thus, human experimentation which often relies on using TTS_2 (i.e., TTS measured 2 minutes after noise exposure) as a predictor of impending noise trauma is of questionable utility, and the CHABA (1965) postulate that TTS_2 is an accurate index of the hazard of a noise is of limited value. The corollary that all exposures that produce an equal TTS_2 are equally hazardous is therefore also of questionable validity.

B. Relationship Between Hearing Loss and Impulse Noise Parameters:

1. The Intensity-Duration Tradeoff: In the current industrial noise regulations, no consideration is given to the specific characteristics of the impulse (e.g., spectrum, repetition rate, etc.). The Coles et al. (1968) criteria attempts to include parameters other than just peak intensity. Briefly, the Coles et al. damage risk criteria (DRC) utilizes a tradeoff between the intensity and the duration of an impulse noise. The DRC is designed to protect 95% of the population and is intended for 100 impulses presented over a period of a few minutes to "several" hours per day. A correction factor is applied to adjust the DRC curve for more or fewer impulses using a 5 dB trade-off per tenfold change in the number of impulses. The intensity-duration trading relation proposed by Coles et al. was evaluated in our laboratories using chinchillas exposed to impulses varying in intensity from 113 dB to 170 dB, and having durations of 40 usec through 200 msec (Henderson and Hamernik, 1978). The chinchillas exposed to impulses lying on the DRC line (50 impulses, 1/min), developed large hair cell losses. These cochlear lesions may or may not be accompanied by parallel losses in hearing sensitivity. The amount of damage could be increased by either increasing the total number of impulses, or by holding the number of impulses constant and decreasing, within limits, the interstimulus interval. One general idea that reemerged from these studies was the notion of a "critical exposure" level (Ward, 1968). Exposures below the critical exposure were not excessively traumatic, while those above it generated significant cochlear pathologies, often far beyond what might be predicted by the DRC. The critical level probably varies with exposure parameters (Roberto et al., 1985).

2. Impulse Noise and Variability: Hodge and McCommons (1966) reported that the variability in TTS following impulse noise exposure was too large to permit generalized statements based upon mean data. Kryter and Garinther (1966) also say essentially the same thing in summarizing their own data; however, they go one step further and suggest that the large variability is the result of "tough" and "tender" ears. McRobert and Ward (1973) suggest that each ear has a critical intensity for a given nonreverberant impulse. Impulses below the critical level induce little or no TTS, regardless of the N; impulses above the critical level produce a TTS that grows by 5 dB for each tenfold increase in N. (See Price, 1983 for additional discussion of the critical level). To further complicate the issue, we have also found that as the threshold of damage is approached, animals will divide into two "Kryter-like" groups, i.e., "tough" and "tender" ears. Above and below the critical level, the amount of damage was relatively homogeneous; however, tremendous variability between subjects was usually associated with the transition region. Spoendlin (1976) has also commented on the extreme variability resulting from impulse noise exposure.

Some of our early data (Eames et al., 1975) suggests that there is also a critical intensity that is related to a conductive failure of the middle ear; i.e., tympanic membrane rupture or other conductive changes occur in the chinchilla at approximately 160 - 166 dB for impulses having a first positive over-pressure duration of 1 msec. Thus, in reviewing the literature on impulse noise, there appears to be at least two major sources of variability: (a) the critical level for developing PTS and cochlear pathology and (b) the critical level for developing a pathological change in the conductive mechanism of the ear.

3. Number of Impulses: The original Coles et al. (1968) DRC recognized the importance of the number of impulses in estimating the potential trauma from an impulse noise exposure. Their basic curve was designed for an exposure of 100

impulses per day with a 5 dB shift of the curve for a tenfold change in N. Before relying too heavily on these figures, perhaps we should consider how this trading relationship originated. In the words of Coles et al., "where exposure is to an occasional single impulse only, it seems reasonable to raise the limits somewhat, and an estimate of 10 dB has been agreed upon for this. The exact adjustment for different numbers of impulses has not been defined since there are obviously an infinite number of variations in the pattern and amount of noise exposure." Thus, the 5 dB for tenfold change in N took hold and is to be found today in the CHABA (1965) report. The point of the above is that this relationship which has been often quoted and accepted is only a best guess and without experimental foundation. Data of McRobert and Ward (1973) show that the function relating hearing loss to the number of impulses is not simple and that each individual may have a critical level for a given impulse. If the impulse exceeds the critical level, then hearing loss with repeated exposure will develop faster than would be predicted. On the other hand, if the impulse is below the critical level, the auditory system appears to be able to withstand many more impulses. The findings of McRobert and Ward are for the TTS state. We have obtained similar results for the chinchilla when PTS and hair cell counts were measured (Roberto, et al., 1985). More recently, Patterson et al. (1985) have shown, using chinchilla, that, over a limited range of impulse parameters, a more defensible trading relation is a 10 dB change in intensity for a tenfold change in the number of impulses. Experiments such as this need to be extended in order to establish the generality of this latter result.

4. Repetition Rate: The Coles et al. DRC, as well as criteria that are based upon equal energy considerations, both neglect the rate of presentation of the impulses as a factor in the production of hearing loss. With repetition rates less than 1/sec, the acoustic reflex can have a protective effect. Ward et al. (1961) exposed human subjects to impulses presented at interstimulus intervals (ISI) of 1, 3, 9, or 30 seconds. Because there was no difference between the level of TTS for each group, it was concluded that when the ISI is greater than 1/sec the repetition rate has little or no effect on PTS. The conclusions of Ward et al. (1961) may not be generalized to all impulse presentations. Perkins et al. (1975), using blast waves, compared the hearing loss produced by 50 impulses of 155 dB and 1 msec A-duration; the impulses were presented at either 1/min or 10/min. There were distinct differences between groups; the faster repetition rates produced much larger amounts of TS, PTS, and hair cell loss than the lower repetition rates. The effects are almost certainly independent of the influence of the acoustic reflex because the ISI at the highest repetition rate is longer than the reflex decay time. While we are a long way from understanding the effects of temporal spacing of impulses on hearing loss, it seems likely that temporal sequencing is an important part of an impulse noise exposure.

This report will describe a set of interrelated experiments and the protocol for those experiments, which may help to formulate some of the "rules" that govern the development of hearing loss from impulse noise (blast wave) exposures.

III. SUMMARY STATEMENT OF PROGRESS

A. Method: During the first year of this contract our primary goal was to obtain hearing threshold data, tuning curves and histological data on chinchillas that were exposed under a variety of conditions to low frequency energy-content blast waves. The source of these blast waves was a modified 6" x 6" cross section shock tube which terminated in an exponential horn. A minimum of five animals constituted an experimental group. The experimental groups that were run are

detailed in Table I. Twenty-one groups of animals constituted this phase of the contract, for a total of 109 animals exposed. The shock tube produced a blast wave that had the bulk of its energy in the octave band centered at 125 Hz. The data set for each exposed animal consisted of preexposure measures of hearing, recovery threshold measures, permanent threshold shift (PTS) measures and histology. Three preexposure audiometric thresholds were measured at 0.5, 1.0, 2.0, 4.0, 8.0, 11.2, and 16.0 kHz. Postexposure recovery functions were measured on each animal at postexposure times of $t = 0, 2, 8, 24$, and 240 hours at test frequencies of 0.5, 2.0 and 8.0 kHz. At 30 days postexposure three final audiograms were collected on each animal at each of the audiometric test frequencies to establish each animals PTS. In addition, tuning curves were collected for each animal at probe frequencies of 0.5, 1.0, 2.0, 4.0, 8.0 and 11.2 kHz prior to exposure and at 30 days postexposure. After the thirty-day testing was complete, each animal was sacrificed by decapitation and the cochlea was examined using the surface preparation histology procedure which yields a quantitative analysis of the sensory cell population in the cochlea.

B. Data Analysis: The experimental paradigm employed resulted in an extremely large quantity of data that required description and analysis. Thus it became evident that if we were not only to analyze the data from these 109 animals but were to essentially repeat this analysis for an additional 315 animals (i.e. 105 animals for each of the other 3 blast wave sources) we would need to develop an appropriate protocol for dealing with a large quantity of data.

Descriptive Procedures: In the initial year of the project, computer software was developed to serve as a data base for all of the experimental animals used in the laboratory. Each animal's results (preexposure thresholds, exposure parameters, recovery thresholds, postexposure thresholds, preexposure and postexposure tuning curves, and histology) are saved on disk in random-access files. By using custom software written in conjunction with this data base, we are able to compute summary statistics and prepare appropriate data summaries. Additional custom-written software is employed with the laboratory animal data base to prepare graphs showing the relation among any of the experimental variables. The process for creating such graphs is therefore greatly simplified and allows the interpretation of data and construction of figures much more rapidly and efficiently than has been our experience in the past.

Inferential Statistics: Once the many dependent variables have been summarized and displayed (i.e., described), the next problem was to make inferences concerning the independent and dependent variables which would allow us to interrelate the several diverse realms of data; i.e. (1) thresholds, (2) tuning curve statistics (e.g. Q_{10dB}, high frequency slope, low frequency slope), (3) histology, and (4) exposure variables. Since complex analyses are often necessary, a commercial statistical package ($SPSS^X$, 1986) was chosen. (A typical analysis that is often used is a three-way mixed model analysis of variance with repeated measures on one factor.) The laboratory data base described briefly above is employed to format the data prior to analysis by $SPSS^X$.

C. Hardware Employed: A number of different computer systems have been installed to satisfy the needs of the current project. Block diagrams of each of the computer systems employed in the project are included in this report. Briefly; a Digital Equipment Corporation (DEC) MicroPDP-11/73 microcomputer is used to collect evoked potentials from experimental animals. Software has been developed for

controlling simultaneous stimulus presentation and data collection and allows the collection of unmasked or masked thresholds using the auditory evoked potential.

Two COMPAQ 286 Deskpro personal computers are used in the acoustics laboratory to collect and analyze acoustic waveforms. A third COMPAQ 286 Deskpro serves to support the acoustics laboratory for software development and data acquisition.

An Apple Macintosh II workstation is used in the histology laboratory to collect and maintain the histological results obtained from the surface preparations of the cochlear tissues. Custom software has been developed to allow a microscope user to enter and manipulate a variety of cell populations or other histological variables. After data entry, the total length of the basilar membrane is computed and data displayed on a place/frequency map.

A second DEC MicroPDP-11/73 was installed to serve as a host for all other computers in the laboratory and provide access to large mass-storage devices, a magnetic tape subsystem, plotters and printers. The host runs a time-sharing operating system which is compatible with the real-time operating systems employed in collecting evoked potentials. Software is developed on this machine and transferred to the evoked potential computers using floppy disk or serial line. The laboratory data base programs described above run on the host system as well as a number of other programs required for the operation of the laboratory and support of the project. The other two MicroPDP-11/73 microcomputers, the three COMPAQ 286 Deskpro personal computers and the Macintosh II workstation are connected to the host and transfer information using KERMIT. In addition, the host is also connected to a ROLM data switch via a DTI to allow access to a Data General MV/10000 minicomputer and Burroughs A10D mainframe.

D. Blast Wave Generation: Two blast wave generators were available at the beginning of this contract period: (1) the conventional shock tube which produces a very low frequency energy-content blast wave (125 Hz); and (2) a spark discharge device which produces very high frequency content blast wave (5 kHz). During the first year two additional shock tubes which operate on a "quick release" valve principle were built and installed. The larger of the two new tubes produces a primary blast wave with most of its energy concentrated in the 1 kHz octave band. Thus, with this series of four blast wave generation devices, it is possible to simulate a wide variety of blast wave configurations in a laboratory environment.

IV. DETAILED REPORT

A. Methods: The basic experimental protocol that is common to all of the experiments consists of the following steps: (1) Preexposure audiograms and TC's are measured on each animal. (2) The animals are exposed to noise under well controlled conditions. The temporal and spectral characteristics of the noise are recorded. (3) The animal's evoked response thresholds are re-determined immediately after exposure and at regular intervals after exposure. At 30 days postexposure, the audiogram is again measured to establish the animal's permanent threshold shift, (PTS), and postexposure TC's are once again collected at all audiometric test frequencies. (4) The animals are sacrificed and their cochleas are then prepared for microscopic analysis. Cochleograms, which provide a quantitative description of the extent and location of the hair cell lesions, are prepared for each cochlea.

Subjects: The chinchilla was used as the experimental animal. Over the years, the chinchilla has been used in a wide variety of auditory experiments and consequently, much is known about its threshold (Miller, 1970; Salvi et al., 1978), psychophysical tuning curves (McGee et al., 1976; Salvi et al., 1982a), threshold for gap detection (Giraudi et al., 1980) and amplitude modulated noise (Salvi et al., 1982b). These psychophysical results indicate that the chinchilla's hearing capabilities are quite similar to those of man. The chinchilla is perhaps the most common animal used in noise trauma research even though there is a general consensus that the species is more susceptible to noise trauma than is man. Thus the chinchilla was chosen as a reasonable animal model for the blast wave studies described in this report.

One hundred and nine (109) chinchillas were used in this study. Each animal was anesthetized [IM injection of Ketamine (12.86 mg/kg), Acepromazine (0.43 mg/kg) and Xylazine (2.57 mg/kg)] and made monaural by the surgical destruction of the left cochlea. A chronic electrode was implanted near the inferior colliculus for single-ended near-field recording of the evoked potential (Henderson et al., 1973; Salvi et al., 1982). The animals were allowed to recover for at least a week before evoked potential testing began.

Host Computer - Hardware Description: A DEC MicroPDP-11/73 supports all the other computers used in the laboratories. A block diagram describing the host computer system is is shown in Figure 1. The host is configured with 2.0 MB of memory, 9-track magnetic tape, a 31 MB fixed, 340 MB fixed and 80 MB removable winchester-technology disk storage and a dual 0.4 MB floppy disk drive. The host computer is configured as a time-sharing system and is connected by a serial line to each of the other microcomputers which are discussed in detail below. Other peripherals which are used by the laboratory systems include two eight-pen digital plotters (Nicolet Zeta-8, Soltec 281), laser printer (DEC LN03), and dot-matrix printer (DEC LA-50). A color-graphics terminal (DEC VT241) and four other video terminals also are available for use by laboratory personnel.

Acquired initially to support only the two other MicroPDP-11/73 laboratory computers as well as two LSI-11/23-based systems, the host's operating system is TSX+ which is compatible with the real-time operating system (RT-11) used on the other LSI-11 systems. TSX+ allows us to develop software on the time-sharing system and move modules to the laboratory units via floppy disk or serial line transfer (KERMIT or VTCOM/TRANSF) which will then run without modification. Data files are easily (although not quickly) transferred from the laboratory systems to the host using the same methods. This arrangement allows us to transfer data to and from any computer system in the laboratory and therefore gives us more flexibility in the laboratory than would be possible without the host system. The host also is connected to a ROLM data switch via a DTI to allow access to the campus Data General MV/10000 minicomputer and Burroughs A10D mainframe and to commercial statistical packages.

The laboratory data base described above runs on the host system. In addition, the host runs a number of other programs required for the operation of the laboratory and support of the project which include, but are not limited to, word processing, data bases, statistical procedures, data transformations, printing and plotting.

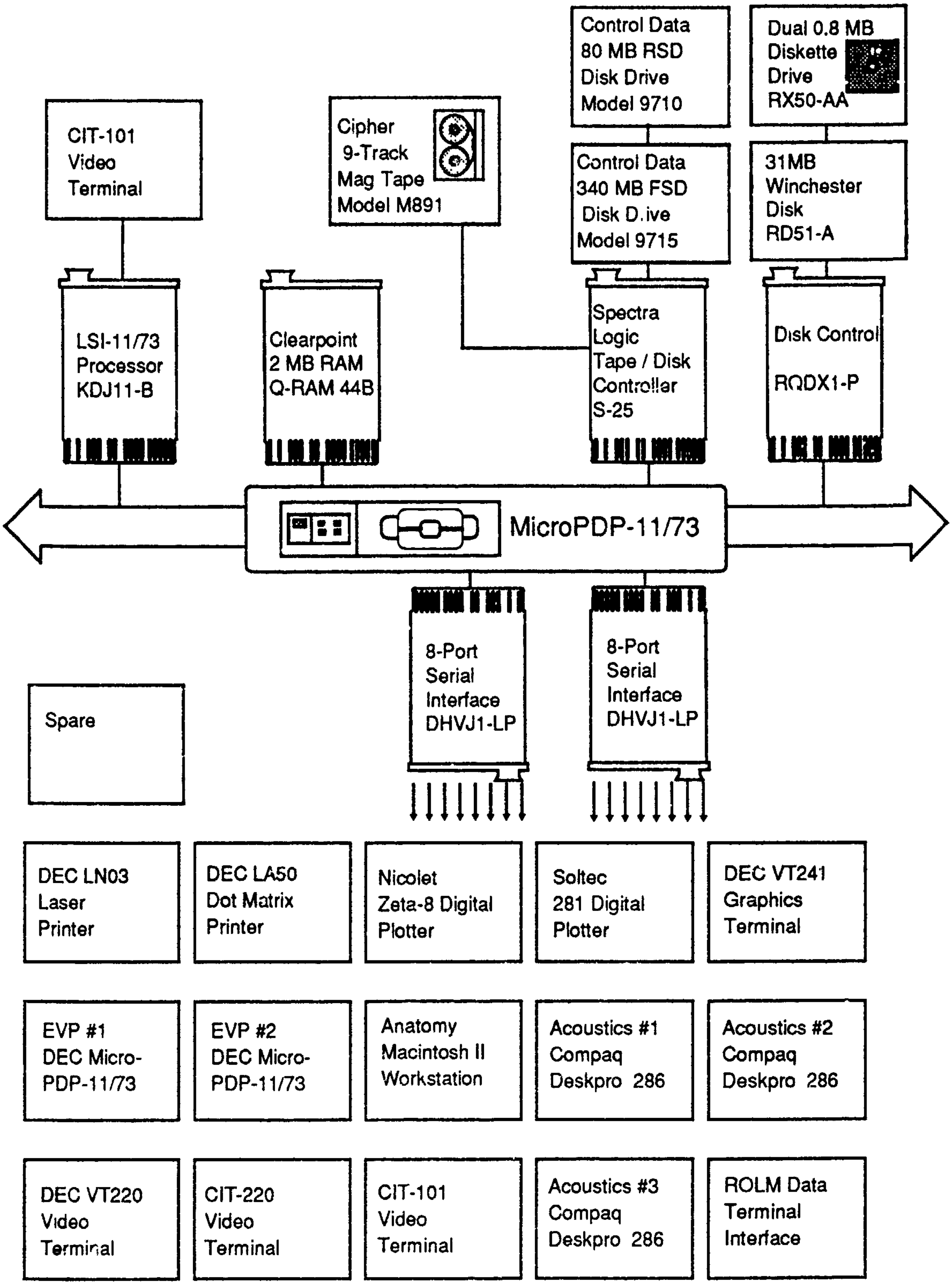


Figure 1. Schematic representation of time-sharing host computer system.

Preexposure testing: Hearing thresholds were estimated on each animal using the auditory evoked potential (AEP). The AEP has been shown to be a valid index of hearing threshold in the chinchilla. The correlation between the behavioral and evoked response measures has been strengthened by directly comparing, in the same animal, estimates of noise-induced behavioral and evoked potential thresholds shifts (Henderson et al., 1983; Davis and Ferraro, 1984). There is a close correlation between the behavioral and evoked response thresholds before, during, and after acoustic overstimulation. In other words, the evoked potential procedure provides a good estimate of the magnitude of noise induced hearing loss. The animals were awake during testing and restrained in a yoke-like apparatus to maintain the animal's head in a constant position within the calibrated sound field. AEP's were collected to 20 msec tone bursts (5 msec rise/fall time) presented at a rate of 10 per second. A general-purpose computer (Digital Equipment Corporation MicroPDP-11/73) with 12-bit A/D converter (Data Translation 3362), timers (ADAC 1601) and digital interface (ADAC 1632) was used to acquire the evoked potential data and control the frequency, intensity and timing of the stimulus via a programmable oscillator (Wavetek 5100), programmable attenuator (Spectrum Scientific MAT) and electronic switch (Coulbourn Instruments S84-04). The electrical signal from the implanted electrode was amplified (50,000x) and filtered (30 Hz to 3000 Hz) by a Grass P511J biological amplifier and led to the input of the A/D converter where it was sampled at 20 kHz (50 msec period) over 500 points to obtain a 25 msec sampling window. Each sampled waveform was analyzed for large amplitude artifacts; and if present, the sample was rejected from the average and another sample taken. Averaged AEP's were obtained from 250 presentations of the 20 msec signal. Each waveform was stored on disk for later analysis. A block diagram of this system is shown in Figure 2.

Thresholds were measured using an intensity series with 5 dB steps at octave intervals from 0.5 to 16.0 kHz and at the half-octave frequency of 11.2 kHz. Threshold was determined to be one half step size (2.5 dB) below the lowest intensity that showed a "response" consistent with the responses seen at higher intensities. The intensity resolution of our method is 5 dB. The average of at least three separate threshold determinations at each frequency obtained on different days was used to obtain the preexposure audiogram.

Tone-on-tone masking functions (i.e., AEP tuning curves, see e.g., Salvi et al., 1982a) were measured on each animal at six probe frequencies between 0.5 and 11.2 kHz presented at 15 dB above the preexposure threshold. A simultaneous masking paradigm was used (McGee et al., 1976). The probe tone had a duration of 20 ms and the intensity was set at 15 dB sensation level at the given test frequency. A simultaneous pure tone masker was presented at increasing levels until the masker just abolished the evoked potential elicited by the probe tone. The procedure was repeated over a range of masker frequencies around the probe tone to yield a "V" shaped masking function. The AEP has been shown to provide as good an estimate of the frequency selectivity as that obtained by behavioral techniques (Salvi et al., 1982). It also shows that a small population of neurons within a restricted frequency band are contributing to the AEP at near threshold intensities. The advantage of the AEP tuning curves (TC) is that they provide an independent method of assessing frequency selectivity and a method that is much easier to apply than behavioral techniques. Ten masker frequencies (from a Wavetek Model 23 programmable frequency synthesizer) distributed in frequency above and below the probe tone frequency were presented in an intensity series with 5 dB steps. The masked threshold was taken as one half a step size (2.5 dB) above the last masker intensity that resulted in a "response". TC's were run on 107 chinchillas from which 650 TC's

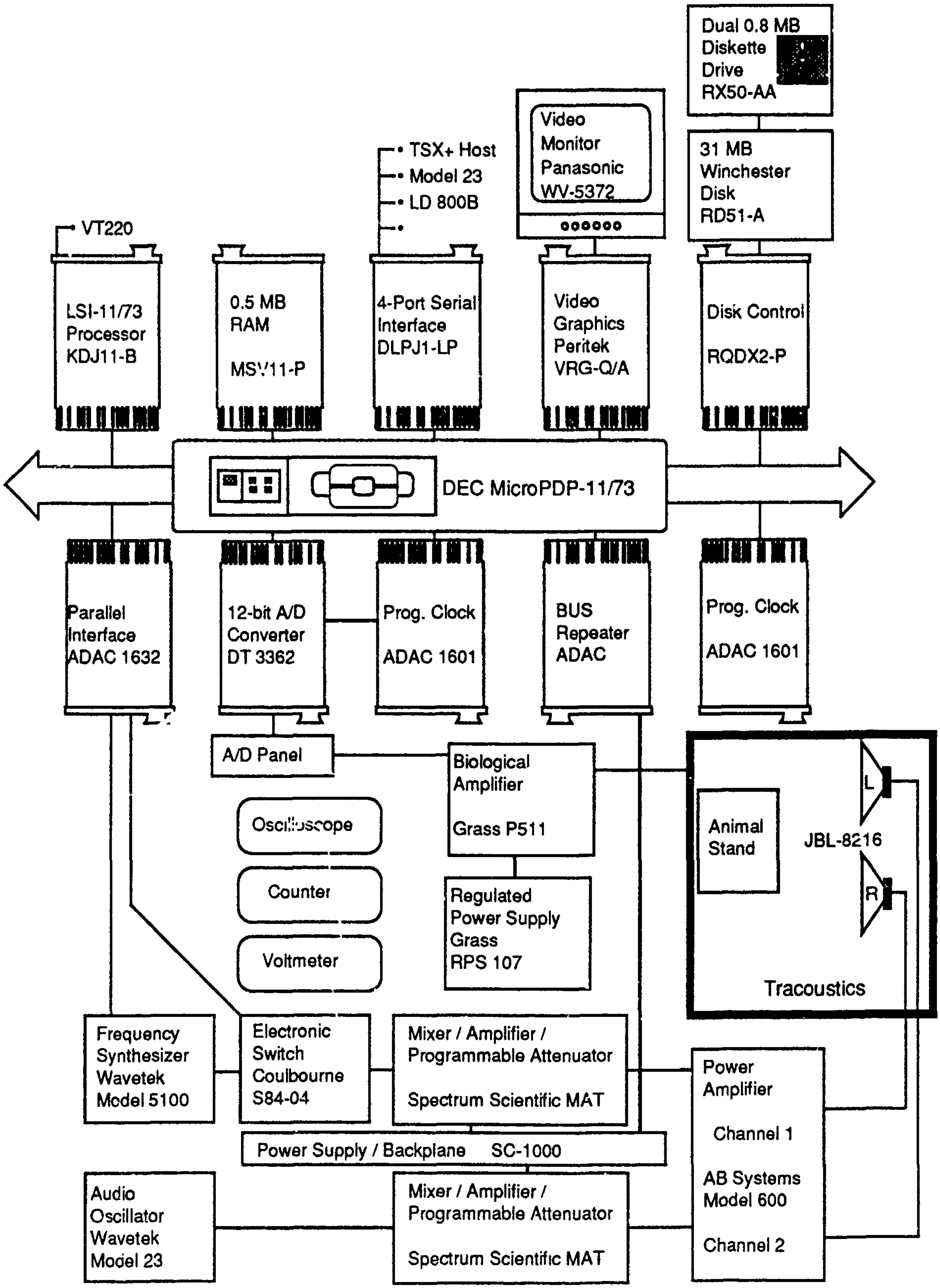


Figure 2. Schematic representation of evoked potential laboratory computer system.

were obtained. The individual animal data is tabulated in the three volume compilation of data included with this report. These TC data will be analyzed during the second year.

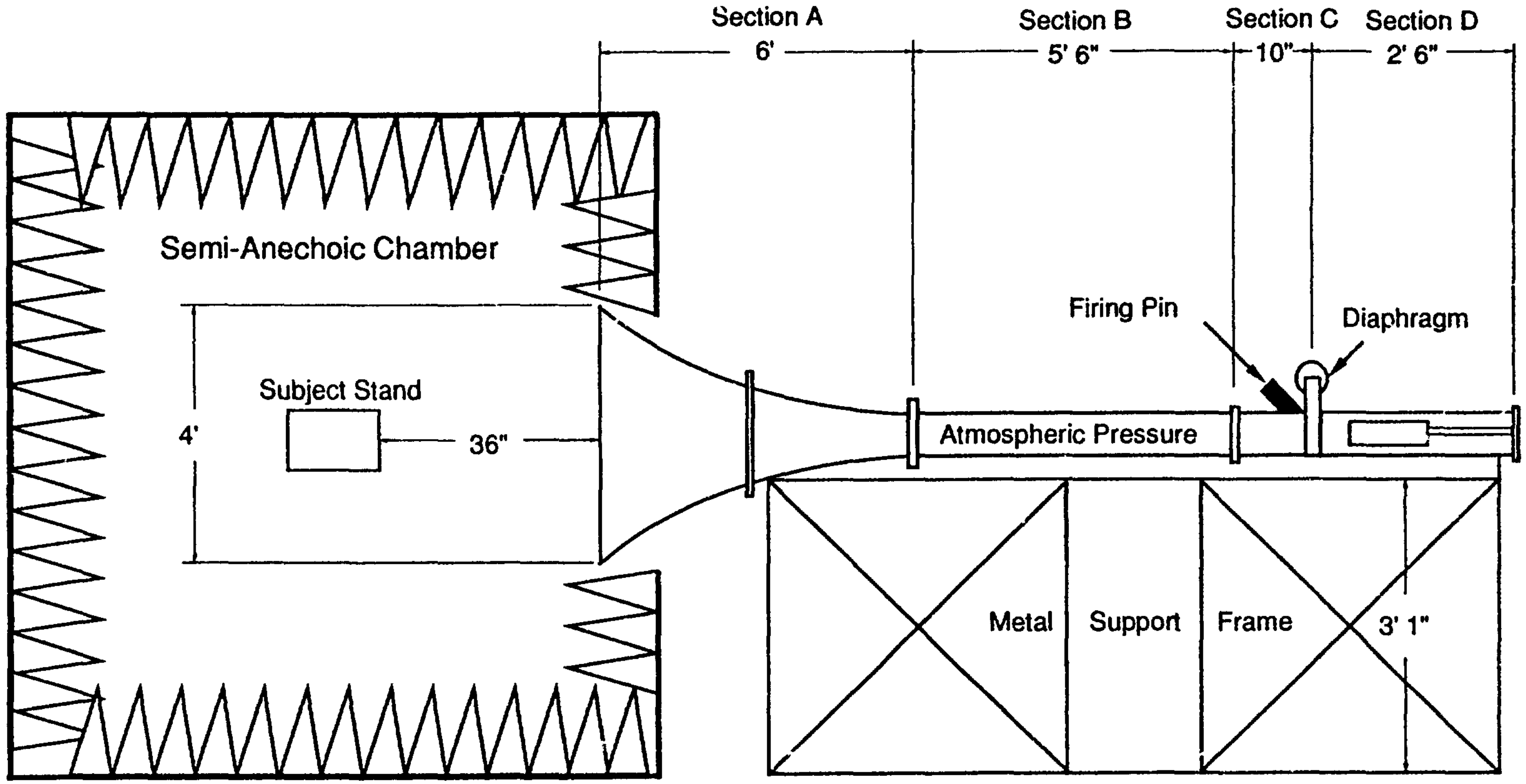
Impedance measures: The measurement of tympanometric functions and impedance was not part of the original protocol of this study. However, when it became obvious that individual variability might be quite large, the decision was made to try and assess middle ear function before and after exposure since damage to the middle ear conductive structures could be one source of variability (Eames et al., 1975).

Prior to each exposure, and immediately following the first postexposure threshold measurement, tympanometry was performed on each animal to monitor middle ear function. Tympanometric measurements were performed by monitoring the acoustic conductance (Ga) and acoustic susceptence (Ba) outputs of an acoustic admittance meter (Grason Stadler 1723) with a strip-chart recorder. Tympanograms were individually recorded at two probe frequencies (220 and 660 Hz) with decreasing ear canal air pressure (+200 to -300mm H_2O). During testing, the animal was restrained in a specially designed holder to prevent head and body movement. All data were corrected to the plane of the tympanic membrane using the MAX/MIN procedure (Margolis and Smith, 1977). Tympanograms reflecting the acoustic conductance (Ga) and susceptence, (Ba) at various canal pressures were converted to acoustic resistance (Ra), reactance (Xa), and impedance (Za) using the relations derived by Margolis and Popelka (1977).

Blast Wave Generation, Measurement and Analysis: A principal requirement for this study was the precise measurement and recording of the blast wave. The computer system used for this purpose was a Compaq 286 Deskpro personal computer using the ASYST™ application package (ASYST™ Software Technologies, Inc., Rochester, NY). The blast wave was first digitized and then recorded in storage devices (e.g., hard disk or magnetic tape). By using the customized software developed in our laboratory, each digitized blast wave was analyzed to extract characteristics such as the total acoustic energy, energy spectrum, peak and root-mean-square (RMS) sound pressure level (SPL) etc. The blast waves employed in this study as well as those to be used in subsequent studies are generated by one of the following three techniques: (1) Electrical Spark Discharge, (2) Conventional Shock Tube, and (3) Two different diameter valve-controlled shock tubes ("Lamont driver").

The blast waves generated by these different devices have a variety of physical characteristics; e.g., the electrical spark discharge produces the highest peak spectral frequency (around 5.0 kHz) while the conventional shock tube has the lowest peak spectral frequency at around 125 Hz. The other two sources are intermediate. By varying the discharge energies or pressures, a wide dynamic range of operation can be achieved, i.e. peak SPL from 150 dB to in excess of 180 dB.

A schematic representation of the blast wave exposure test facility using the conventional shock tube is illustrated in Figure 3. The SPL of the blast wave can be controlled by systematically adjusting the pressure in the compression section. The blast wave was measured using a transducer located on the center line and 36 inches from the outlet of the shock tube. The experimental animal was mounted next to the microphone.



Section A: Exponential Horn (Throat - 6" X 6", Exit - 4' X 4')
Section B: Expansion Tube (6" X 6")
Section C: Transition Section
Section D: Compression Section (Diameter - 5")

Figure 3. Schematic Side View of the Conventional Shock Tube.

The shock tube, in its most simple form, is a device in which a plane shock wave is produced by the bursting of a diaphragm which separates the high pressure (compression) section from the constant area (6" x 6") expansion section which is kept at atmospheric pressure. The expansion section terminates in a 6' exponential horn having a 4' x 4' exit. The nearly instantaneous release of the high pressure volume of air generates a series of compression waves which propagate into the expansion section and rapidly coalesce into a shock front a few diameters downstream of the diaphragm. The horn exit is mounted in a semi-anechoic enclosure. By varying the pressure in the compression section and the configuration of the horn throat, various blast wave profiles can be achieved (Hamernik et al., 1973).

Figure 4 illustrates the instrumentation used in the blast wave measurement. Two different types of transducers are used to convert the dynamic acoustic pressure into an analog signal. The B&K 1/8 inch microphone (Type 4138) and the PCB crystal microphone (Model 112A22) were selected because of their ability to record high peak levels and their relatively fast rise times. A B&K microphone preamplifier (Type 2639), a B&K measuring amplifier (Type 2606), and a PCB six-channel amplifying power unit (Model 483A08) were used to amplify the analog signals from the B&K and PCB microphones respectively. The amplified analog signals are monitored on an oscilloscope.

To avoid aliasing, it was necessary to filter the analog signal using an analog (anti-aliasing) lowpass filter prior to sampling. The cutoff frequency of the anti-aliasing filter is based on the sampling frequency of the data acquisition system. It must be less than the Nyquist frequency, i.e., half of the sampling frequency. In practice, one-third of the sampling frequency is normally chosen. Note that the B&K measuring amplifier (Type 2606) has a built-in lowpass filter with a cutoff frequency of 22.5 kHz which can also be used as an anti-aliasing filter.

The schematic diagram of the PC-based data acquisition and analysis system is illustrated in Figure 5. A COMPAQ 286 Deskpro PC is configured with 1.2 MB random access memory (RAM), 30 MB winchester disk drive, 10 MB tape drive and EGA graphics adaptor. A 12-bit, 16-channel A/D converter subsystem (RC Electronics ISC-16) allowed rapid digitization of the blast wave at a maximum of one million samples/second (1.0 MHz or 1 usec sampling period). The fast sampling rate helps in the accurate detection of the peak of the blast wave, one of the primary parameters in this study. The 12-bit resolution of A/D converter provides a reasonably accurate digitization of the analog signals. The acoustics laboratory data acquisition and analysis system was chosen and configured using standard commercial hardware (PC compatible) and software (ASYST™) to allow easy replication and exchange of data.

The programs for performing the data acquisition and analysis are written using the ASYST™ application package. This package not only incorporates many features of standard computer languages such as APL and FORTRAN but also contains many pre-written software tools such as interactive graphics, Fast Fourier Transform (FFT), numerical integration and statistical computations. These features greatly simplify the task of performing the signal acquisition and processing

The flowcharts for these ASYST™ programs are illustrated in Figures 6. The programming of the data acquisition part is shown in Figure 6(a) and is briefly described below.

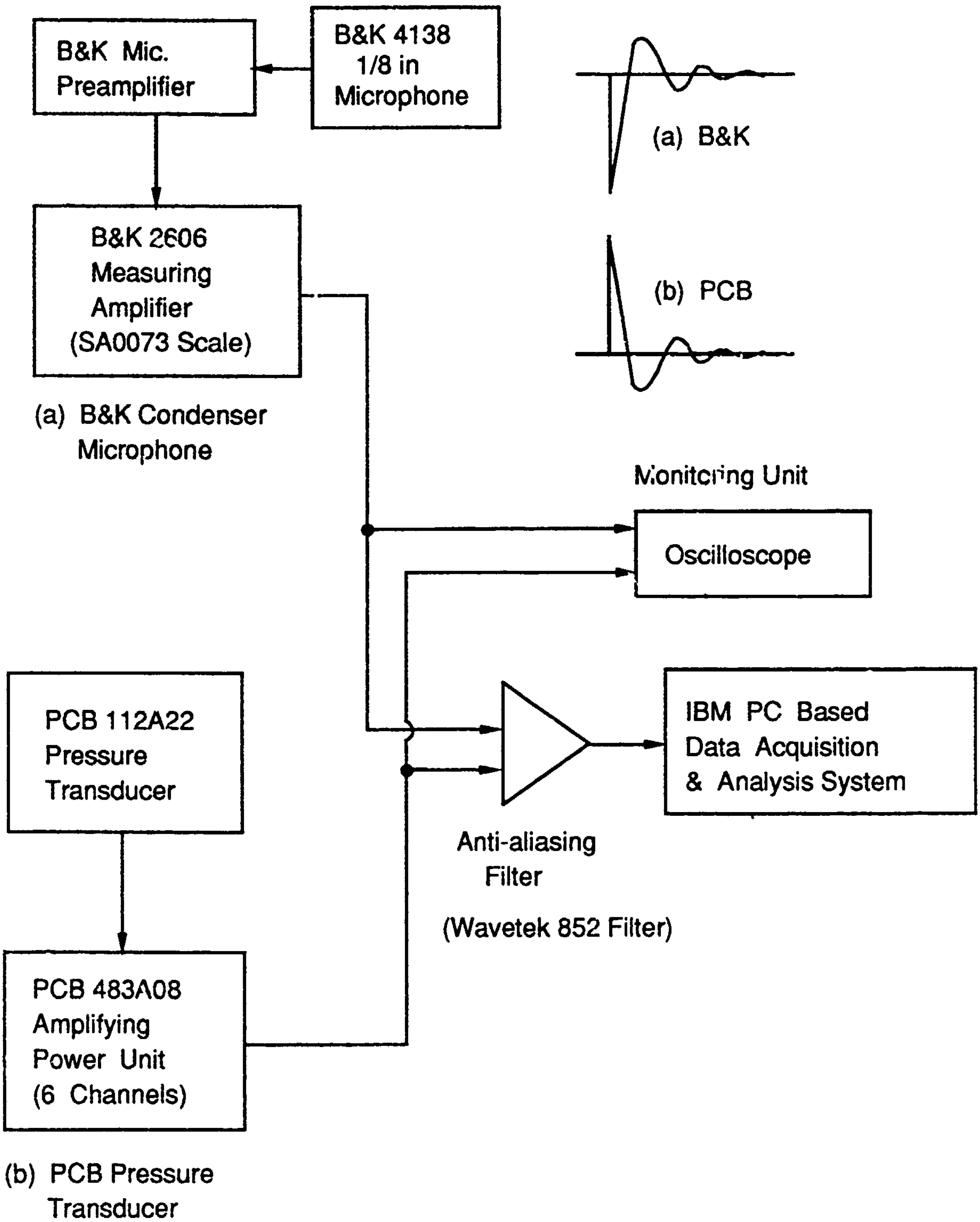


Figure 4. Schematic of Instrumentation Used in Blast Wave Measurement.

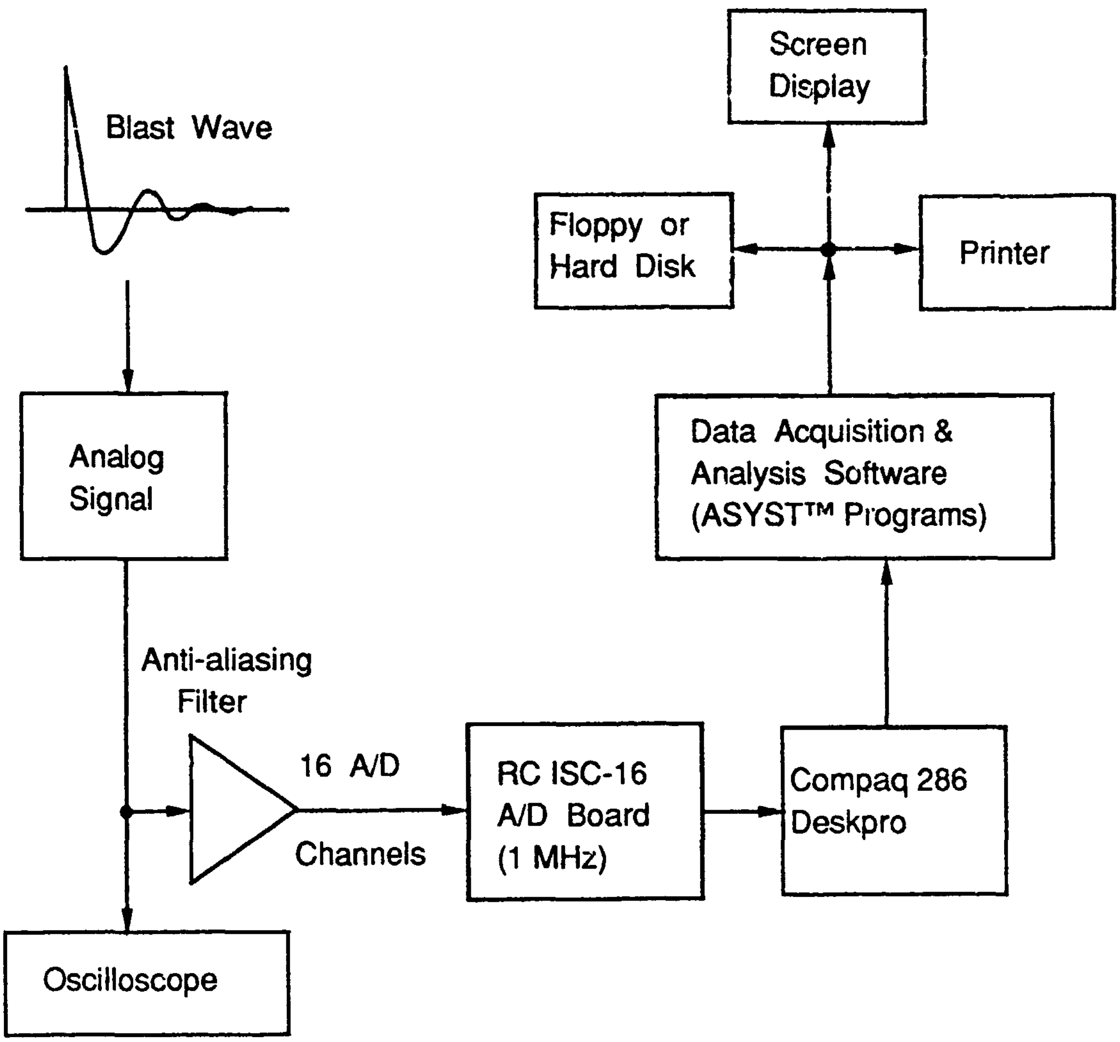
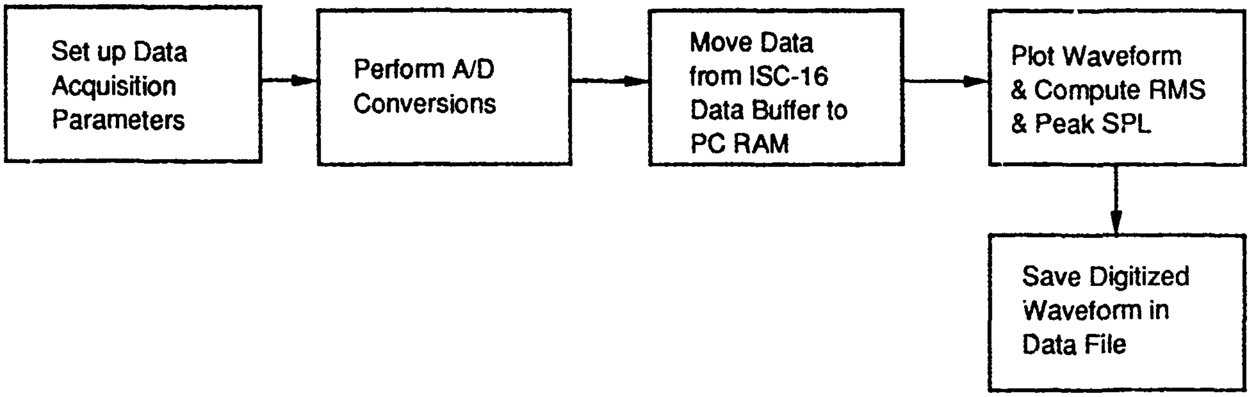


Figure 5. Configuration of the PC-based Data Acquisition and Analysis System.

(a) Acoustics Laboratory Data Acquisition Program.



(b) Acoustics Laboratory Data Analysis Program

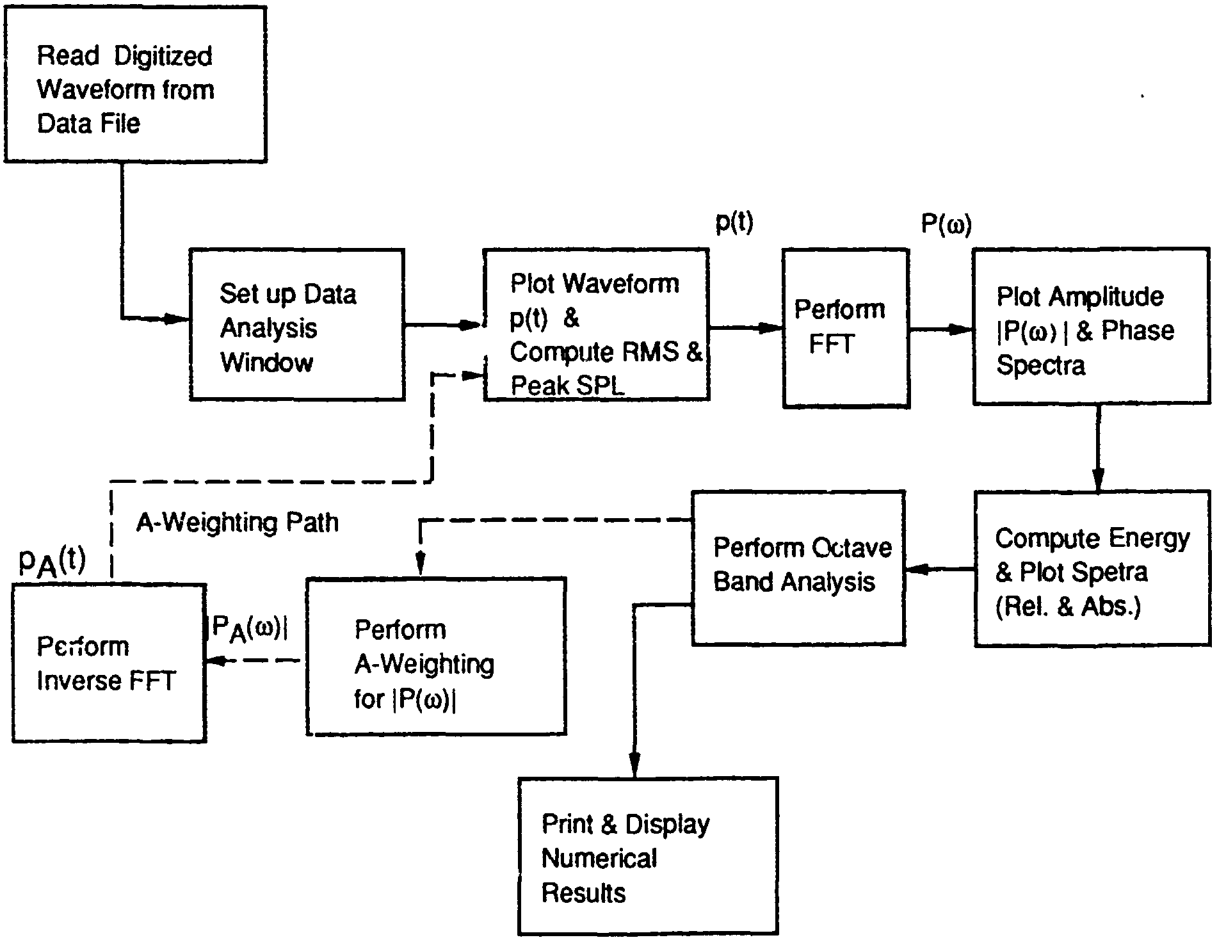


Figure 6. Flowchart of (a) Data Acquisition and (b) Data Analysis Programs using ASYST™ Application Package.

1. Set up the data acquisition parameters for the ISC-16 board such as the sampling time, total number of samples, trigger channel, trigger slope, trigger threshold, pre-trigger delay etc
2. Perform A/D conversions using the 12-bit A/D convertor mounted on the ISC-16 board.
3. Move the digitized data from ISC-16 data buffer to PC RAM.
4. Plot the acquired acoustical waveform and compute the peak and RMS SPL.
5. Save the digitized waveform in a data file for analysis.

The programming of the data analysis part of the setup is shown in Figure 6(b) and is briefly described below.

1. Read the digitized waveform from the data file.
2. Set up the parameters needed for the data analysis window such as the sampling time, starting time and number of data points of the analysis window, and the number of data points to be skipped.
3. Plot the pressure-time waveform, p(t), and compute the peak and RMS SPL.
4. Perform the FFT of p(t) to obtain the spectral components, $P(\omega)$.
5. Plot the amplitude and phase spectra using $P(\omega)$.
6. Compute the total acoustic energy and plot the energy spectrum in both relative units (dB) and absolute units (J/m^2).
7. Perform an octave band analysis on the computed energy.
8. Print and display the computed results such as the data window size, SPL, energy etc.
9. Perform A-Weighting computations for $|P(\omega)|$ based on the standard A-Weighting curve.
10. Perform Inverse FFT using A-Weighted $|P(\omega)|$, i.e. $|P_A(\omega)|$, without changing the phase components to construct the A-weighted pressure-time waveform, $p_A(t)$.
11. Repeat steps 3 to 8 using A-weighted pressure-time waveform, $p_A(t)$.

<u>Exposure of Animals</u>: Each chinchilla was exposed at the same fixed location relative to the horn exit. During exposure the animal was unanesthetized but immobilized in a leather harness (Patterson et al., 1986a). The right pinna was folded back and fixed in place to insure that the entrance of the external meatus was not obstructed and the position of the entire animal was adjusted so that the cross sectional plane of the meatus was oriented parallel to the advancing shock front i.e. a normal incidence.

Each experimental group of animals generally consisted of five animals. Each animal was individually exposed to one of the exposure conditions shown in Table I. A total of 109 animals were used to complete this experimental paradigm.

<u>Postexposure Testing</u>: After the exposure was complete, threshold recovery functions were measured at 0.5, 2.0 and 8.0 kHz at 0, 2, 8, 24 and 240 hours after removal from the noise (using the same method as described for preexposure testing). After at least 30 days, final audiograms were constructed using the average of three separate threshold determinations at each of the seven preexposure frequencies. Permanent threshold shift (PTS) was defined as the difference between the postexposure and preexposure thresholds at each individual test frequency. Postexposure AEP tuning curves were collected at the six preexposure probe tones presented at 15 dB above the postexposure threshold.

TABLE I

Table of Experimental Groups

Group	N	Intensity	Number	Rate
1	4	150 dB Peak SPL	1	
2	5	150 dB Peak SPL	10	10 per minute
3	5	150 dB Peak SPL	10	1 per minute
4	5	150 dB Peak SPL	10	1 per 10 minutes
5	5	150 dB Peak SPL	100	10 per minute
6	6	150 dB Peak SPL	100	1 per minute
7	5	150 dB Peak SPL	100	1 per 10 minutes
8	6	155 dB Peak SPL	1	
9	5	155 dB Peak SPL	10	10 per minute
10	5	155 dB Peak SPL	10	1 per minute
11	5	155 dB Peak SPL	10	1 per 10 minutes
12	6	155 dB Peak SPL	100	10 per minute
13	6	155 dB Peak SPL	100	1 per minute
14	5	155 dB Peak SPL	100	1 per 10 minutes
15	6	160 dB Peak SPL	1	
16	5	160 dB Peak SPL	10	10 per minute
17	6	160 dB Peak SPL	10	1 per minute
18	5	160 dB Peak SPL	10	1 per 10 minutes
19	5	160 dB Peak SPL	100	10 per minute
20	5	160 dB Peak SPL	100	1 per minute
21	5	160 dB Peak SPL	100	1 per 10 minutes
Total	110			

Cochlear Histology: Following postexposure audiometric testing, animals were sacrificed by decapitation and the cochleas were immediately removed and fixed. The cochleas were dissected and the status of the sensory cell population was evaluated using conventional surface preparation histology (Engstrom et al., 1966). Briefly, the stapes was removed and the round window membrane opened to allow transcochlear perfusion, via the scala tympani/scala vestibuli with cold 2.5% glutaraldehyde in veronal acetate buffer at 7.3 pH (605 mOsm). Postfixation was performed on the following day with one percent osmium tetroxide in veronal acetate buffer (pH 7.3) for 30 minutes. The cochleas were dissected and the entire sensory epithelium along with the lateral wall structures was mounted with glycerin on glass slides. [See Hamernik et al., (1987) for a more complete description]. The status of sensory and supporting cells were evaluated with Nomarski Differential Interference Contrast microscopy and entered into a data-base on a laboratory computer (Digital Equipment Corporation MicroPDP-11/73 or Macintosh II). Standard cochleograms were then constructed by computing the percent sensory cell loss across the length of the cochlea in 0.24 mm steps. These cell loss figures were then converted into percent loss over octave bands centered at the audiometric test frequencies along the length of the cochlea and correlated with the frequency-place map constructed by Eldredge et al. (1981). The morphometric system is shown schematically in Figure 7.

B. Results: The results of the present experiment are grouped into preexposure, exposure, postexposure, histological, and impedance sections.

Preexposure Thresholds: The mean preexposure thresholds for the 21 groups of animals and the mean preexposure thresholds for all 109 subjects are summarized in Table II and plotted in Figure 8. The mean preexposure thresholds do not differ from Miller's (1970) behavioral audibility curve for the chinchilla when the (approximate 11.1 dB) effects of temporal integration are taken into consideration (Henderson, 1969).

The audiological dependent variables in this report are maximum threshold shift (TS_{max}) and permanent threshold shift (PTS). Each of these variables is computed by subtracting the preexposure from the postexposure thresholds. Thus, each animal serves as its own control subject. Only rarely did a group's mean threshold exceed the adjusted thresholds of Miller (1970) by more than 10 dB. Further, Humes (1984) has suggested that there is little evidence that a preexisting NIHL alters the final level of hearing loss from a subsequent noise exposure. Therefore, any statistical differences in preexposure thresholds should not affect the final conclusions in this report.

Noise Exposures: Pressure-time histories for each of the three intensity waves are shown in Figures 9 through 14 along with the unweighted and A-weighted energy spectra. The absolute energies and relative energy levels for each of the exposures are listed in Table III and illustrated in Figures 15 through 17. The same spectral energy has been replotted in Figure 18 in the conventional octave band format where all three intensity waves can be easily compared.

The impulses do not show a classical Friedlander configuration but rather the first positive overpressure shows two peaks; the first most prominent is generated by the passage of the primary shock front while the second lower level peak is most likely the result of primary wave reflections either in the horn or from the base of anechoic chamber. The A-duration of each of these three impulses was

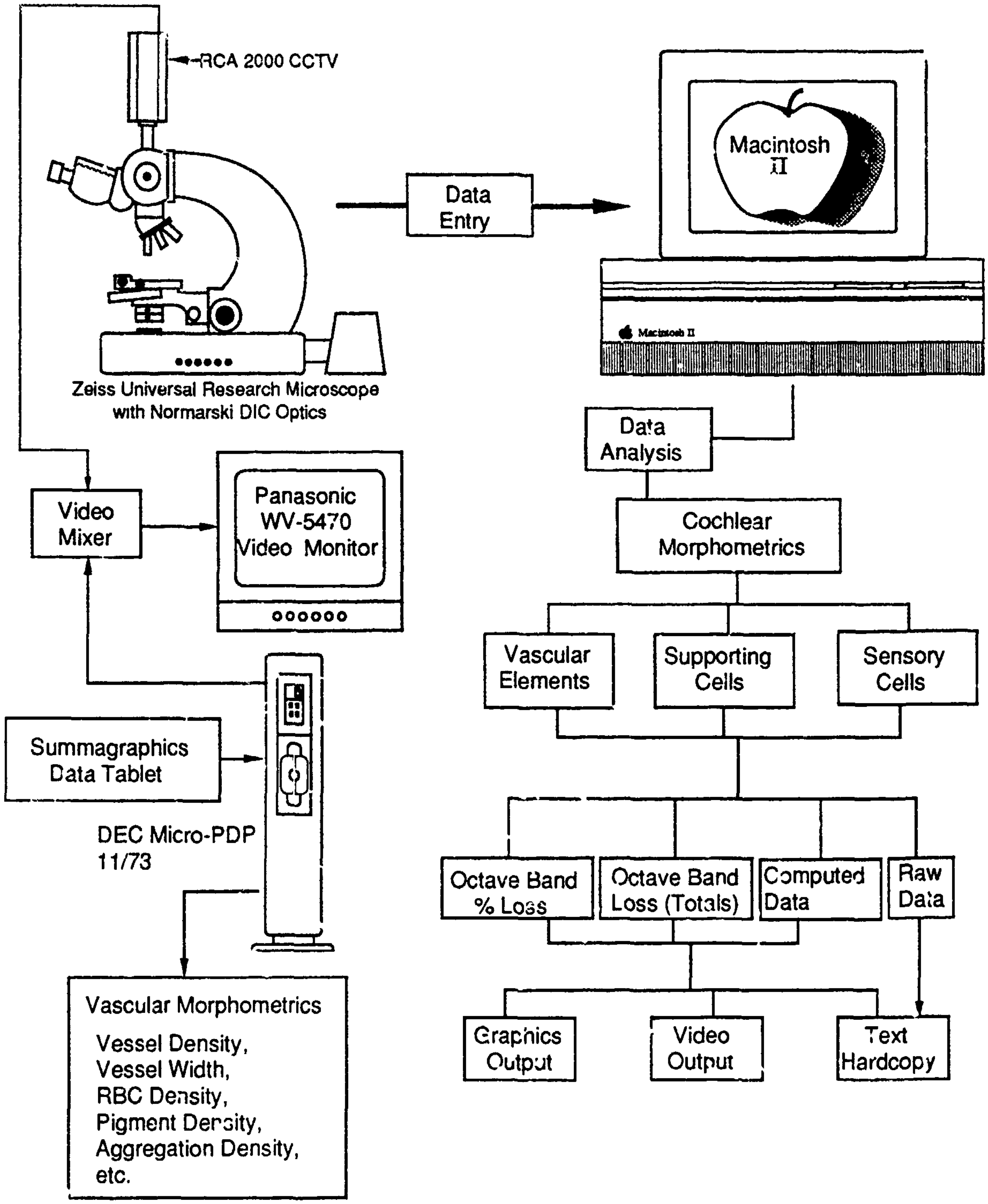


Figure 7. Anatomy Laboratory Temporal Bone Morphometric Analysis Systems.

TABLE II

Preexposure Threshold Means and
Standard Deviations for all Groups

				Test Frequency							
dB Peak	#	Rate	N	0.5	1.0	2.0	4.0	8.0	11.2	16.0	
150 dB	1		4	24.5	20.0	22.5	12.2	28.6	27.9		$\overline{X}$
				10.7	8.5	8.8	5.9	2.9	3.9		s
150 dB	10	10/M	5	21.2	7.2	16.2	4.8	19.2	17.5	26.5	$\overline{X}$
				1.8	4.6	4.3	3.5	2.4	3.7	5.4	s
150 dB	10	1/M	5	16.9	8.7	12.2	2.8	14.8	15.9		$\overline{X}$
				8.4	5.1	4.6	6.4	7.0	8.3		s
150 dB	10	1/10M	5	24.8	10.2	14.8	8.5	21.8	14.2	26.6	$\overline{X}$
				3.3	2.8	6.2	7.0	1.8	7.1	8.9	s
150 dB	100	10/M	5	18.5	5.5	12.5	6.9	17.5	16.5	21.5	$\overline{X}$
				2.5	3.4	6.6	5.6	5.9	8.5	5.5	s
150 dB	100	1/M	6	25.7	15.5	15.0	9.4	22.5	22.5		$\overline{X}$
				6.4	4.1	5.6	6.8	8.2	8.3		s
150 dB	100	1/10M	5	20.8	5.5	4.5	2.5	14.8	10.8	17.5	$\overline{X}$
				2.6	2.2	3.6	4.1	3.5	4.5	7.7	s
155 dB	1		5	10.5	4.8	11.8	4.8	12.8	18.5		$\overline{X}$
				3.6	5.4	5.1	11.9	7.6	2.8		s
155 dB	10	10/M	5	23.2	15.2	14.7	6.8	21.3	24.5		$\overline{X}$
				3.5	3.3	0.7	7.6	7.3	2.2		s
155 dB	10	1/M	5	19.7	13.8	15.4	6.4	20.2	26.2		$\overline{X}$
				2.6	4.6	5.2	0.7	3.2	9.0		s
155 dB	10	1/10M	5	22.9	11.9	16.6	13.2	27.4	32.3		$\overline{X}$
				4.4	3.9	5.3	2.5	4.1	9.5		s
155 dB	100	10/M	6	11.7	5.0	12.2	7.5	16.1	16.4		$\overline{X}$
				5.0	3.6	4.6	7.4	11.8	10.0		s
155 dB	100	1/M	6	16.1	8.6	13.9	5.0	19.7	19.7		$\overline{X}$
				3.2	3.1	5.0	5.1	7.7	4.9		s
155 dB	100	1/10M	5	9.5	5.2	9.5	-3.0	6.8	10.5		$\overline{X}$
				6.2	7.5	5.5	3.8	4.5	6.2		s

TABLE II (continued)

Preexposure Threshold Means and
Standard Deviations for all Groups

dB Peak	#	Rate	N	Test Frequency 0.5	1.0	2.0	4.0	8.0	11.2	16.0	
160 dB	1		6	25.5	15.8	19.5	12.3	29.4	29.0		$\overline{X}$
				4.8	2.2	3.3	7.5	7.4	5.8		s
160 dB	10	10/M	5	18.8	4.8	10.8	0.5	13.5	11.2	19.5	$\overline{X}$
				2.7	4.5	3.9	1.4	2.8	6.1	3.2	s
160 dB	10	1/M	6	16.7	8.0	14.3	3.6	16.7	21.9		$\overline{X}$
				8.2	6.4	7.2	7.1	9.1	12.4		s
160 dB	10	1/10M	5	24.8	11.5	14.8	5.5	17.5	18.5	28.2	$\overline{X}$
				4.8	3.8	3.6	3.8	2.9	4.5	9.7	s
160 dB	100	10/M	5	19.5	4.8	8.8	3.2	19.2	16.5	22.8	$\overline{X}$
				2.2	3.8	5.8	4.2	6.1	3.8	6.3	s
160 dB	100	1/M	5	19.5	12.5	15.7	7.5	21.5	26.2		$\overline{X}$
				7.4	8.1	10.9	9.5	8.7	9.8		s
160 dB	100	1/10M	5	22.8	7.5	12.5	5.5	18.8	17.2	18.5	$\overline{X}$
				1.3	3.7	2.0	2.7	5.3	7.4	7.7	s
Total Population				19.6	9.6	13.7	6.0	19.1	19.7	24.6	$\overline{X}$
(see Figure 1)				6.6	6.1	6.1	6.7	7.8	8.9	9.7	s
				109	109	109	109	109	109	45	N
Miller (1970)				5.1	3.0	2.7	1.9	5.8	9.9	12.1	$\overline{X}$
(750 ms signals)				6.1	4.1	4.7	7.1	5.4	6.7	6.9	s
				36	36	36	36	36	34	36	N
Miller (1970) with correction for temporal integration				16.2	14.1	13.8	13.0	16.9	21.0	23.2	$\overline{X}$

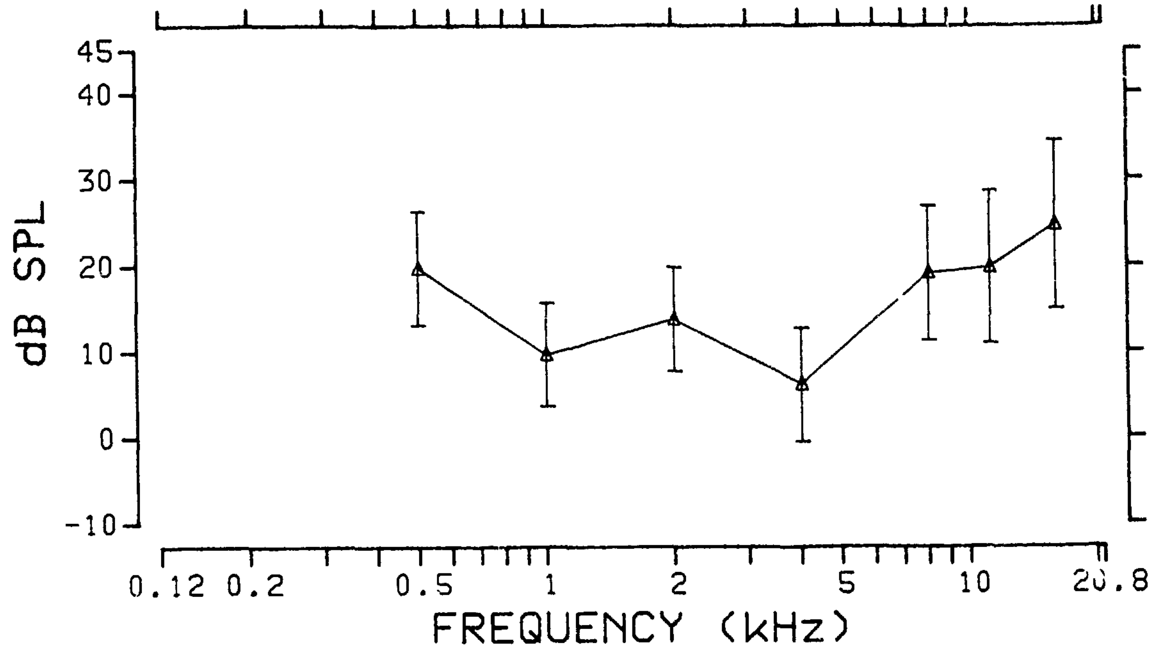


Figure 8. Mean preexposure thresholds for 109 chinchillas.

Table III

Energy Calculations for the Blast Wave Generated
by the Conventional Shock Tube

Peak SPL (dB)	Weight	Absolute Energy (J/m^2) 1X	10X	100X	Relative Energy (dB) re: $1J/m^2$ 1X	10X	100X
150	None	1.06	10.64	106.38	0.27	10.27	20.27
	A	0.13	1.25	12.52	-9.02	0.98	10.98
155	None	1.53	15.27	152.69	1.84	11.84	21.84
	A	0.24	2.38	23.82	-6.23	3.77	13.77
160	None	4.37	43.70	436.99	6.40	16.40	26.40
	A	0.72	7.24	72.36	-1.41	8.60	18.60

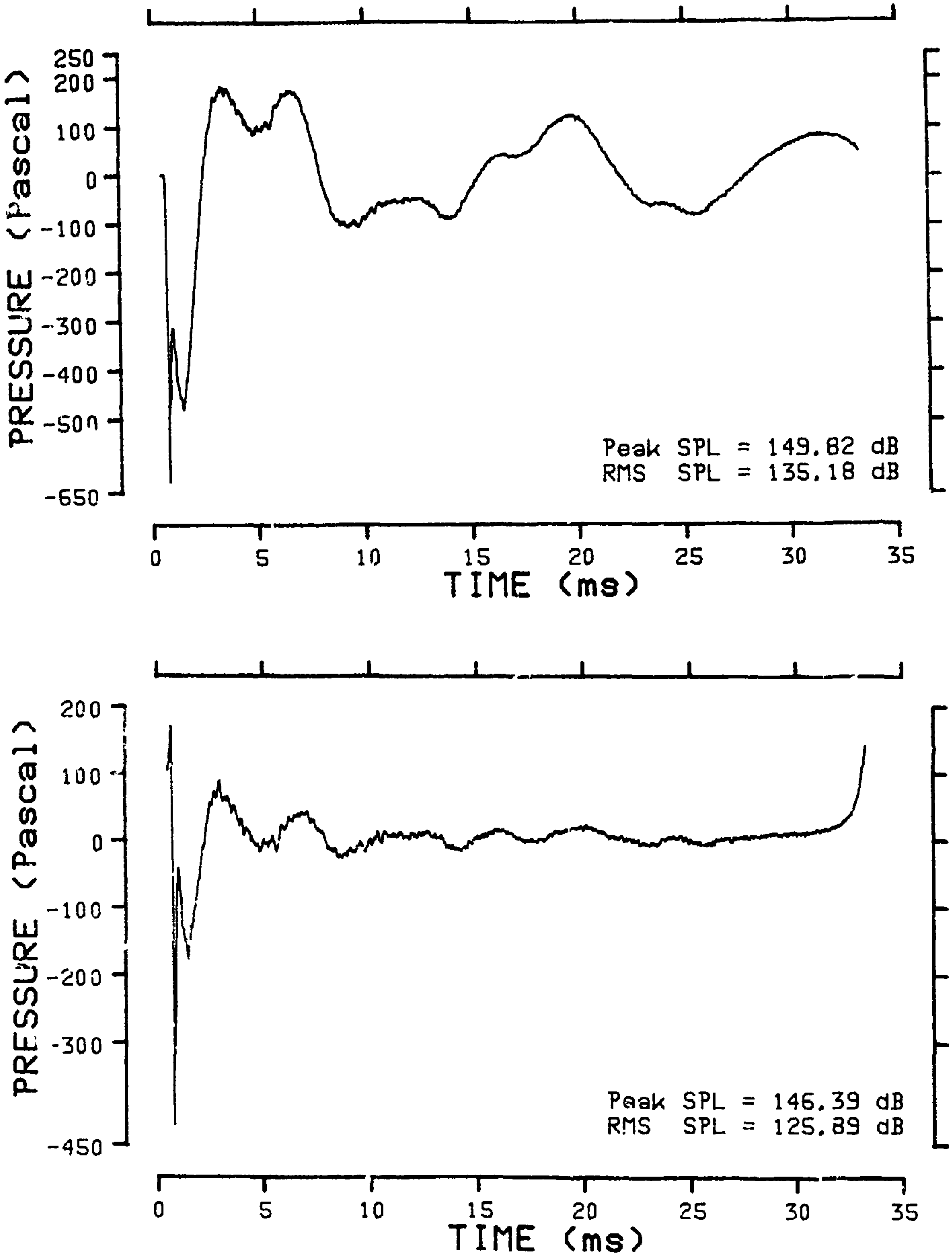
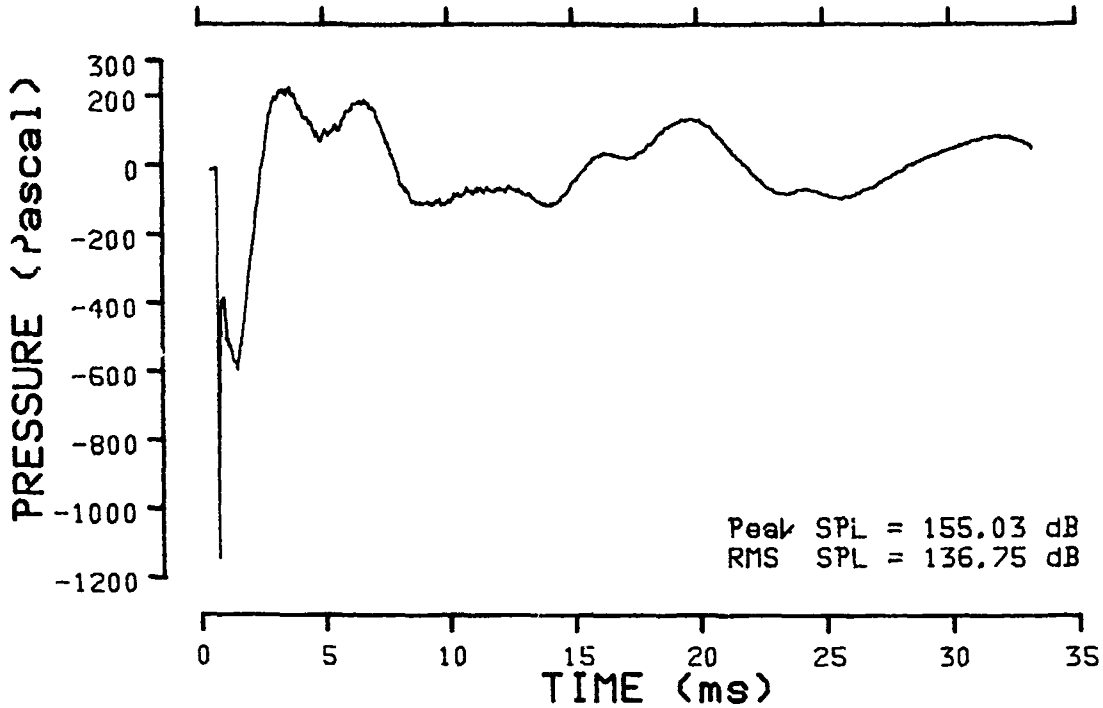


Figure 9. Pressure-time waveforms for the 150 dB peak SPL blast wave. Upper trace is the actual recording. Lower trace is the waveform reconstructed from the A-weighted FFT amplitude spectrum without changing phase.



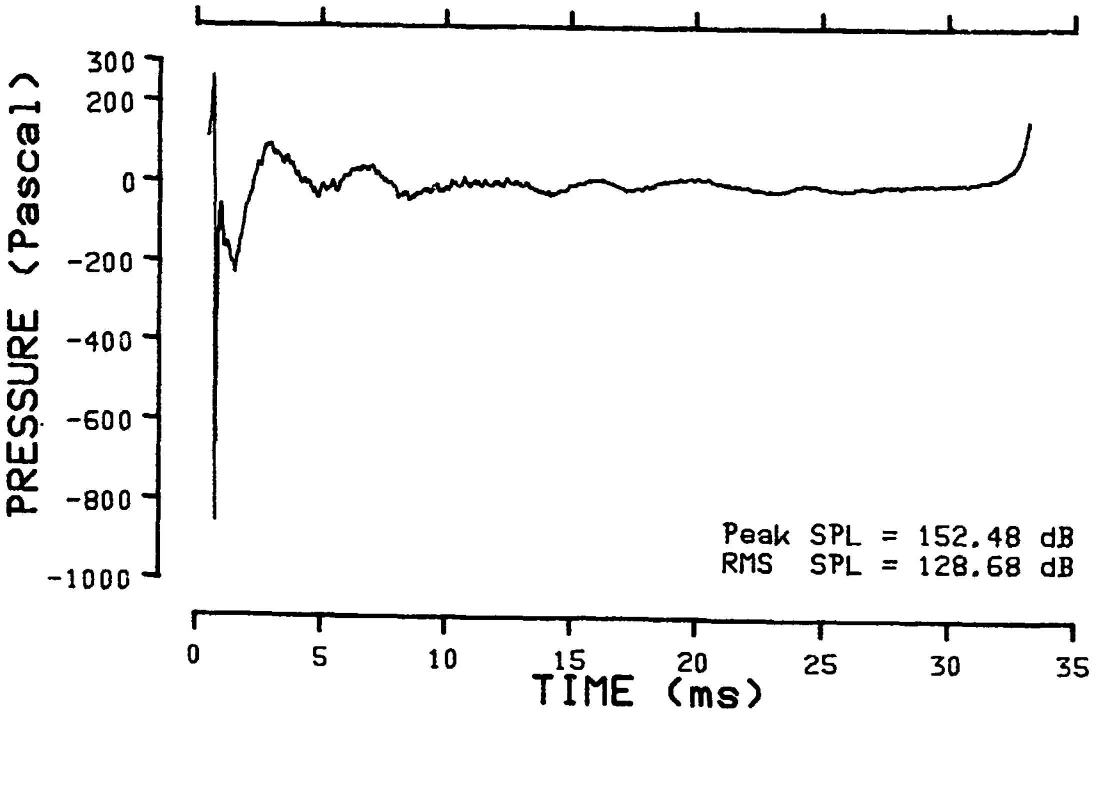


Figure 10. Pressure-time waveforms for the 155 dB peak SPL blast wave. Upper trace is the actual recording. Lower trace is the waveform reconstructed from the A-weighted FFT amplitude spectrum without changing phase.

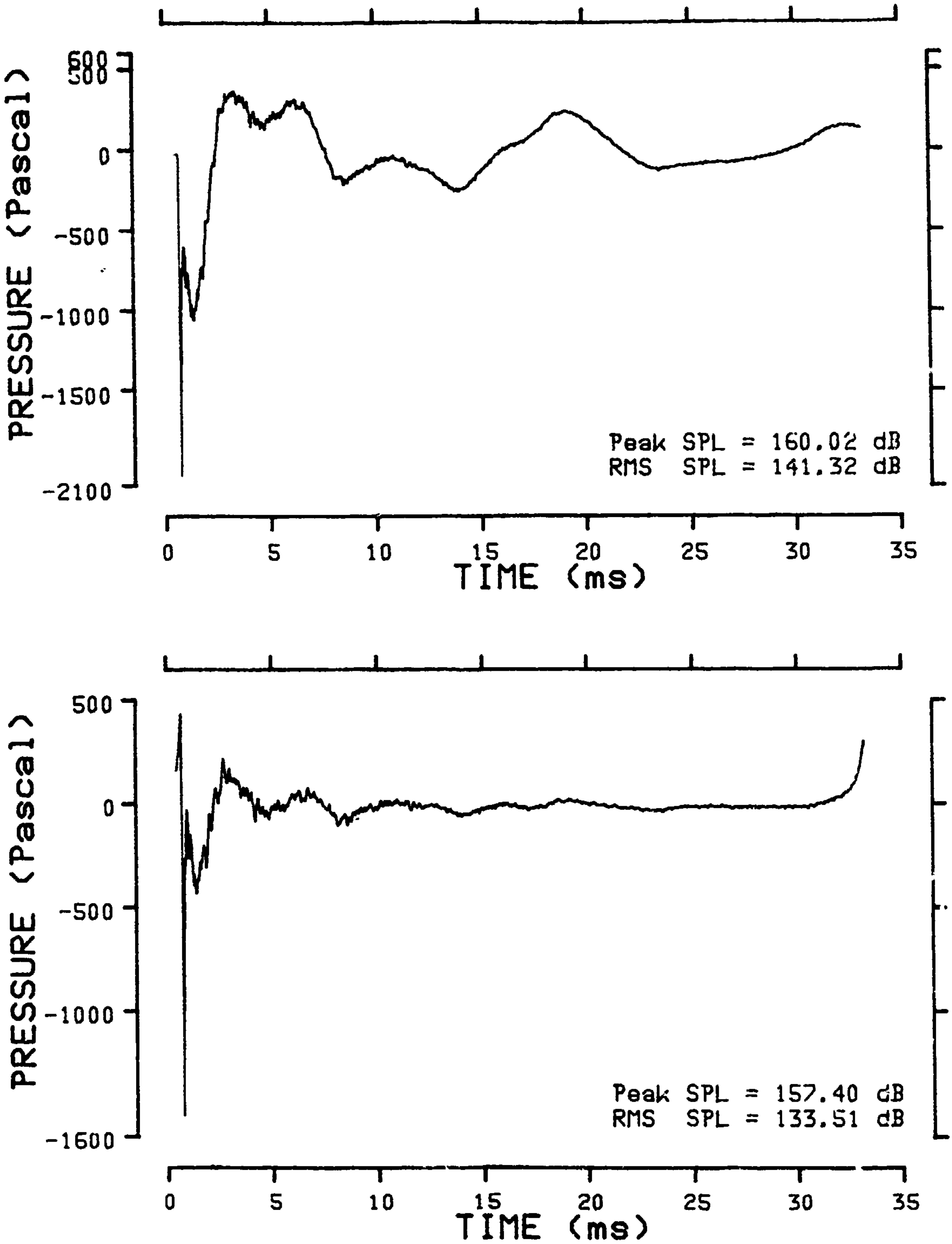


Figure 11. Pressure-time waveforms for the 160 dB peak SPL blast wave. Upper trace is the actual recording. Lower trace is the waveform reconstructed from the A-weighted FFT amplitude spectrum without changing phase.

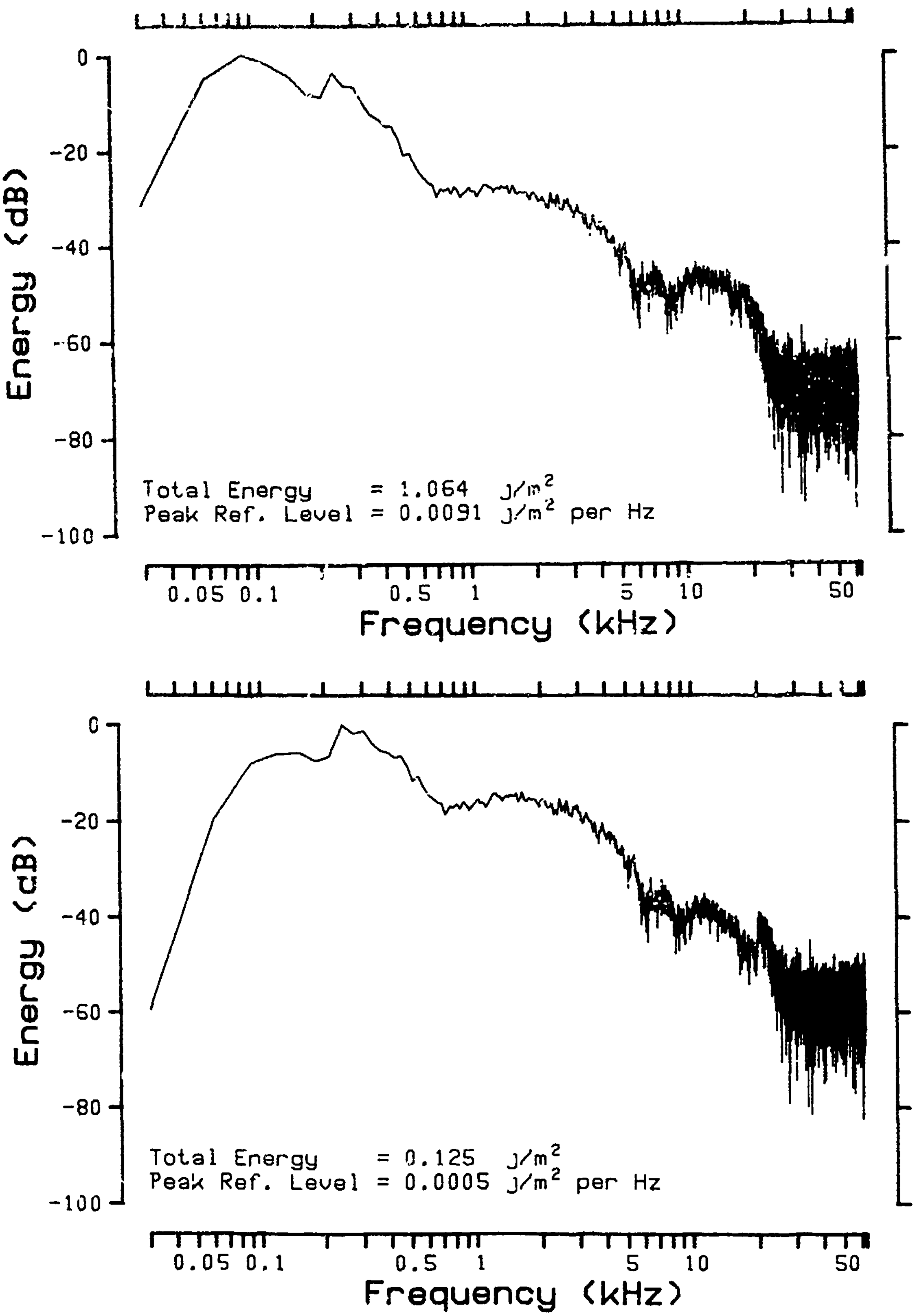


Figure 12. The unweighted (upper) and A-weighted (lower) energy spectra for the 150 dB peak SPL blast wave.

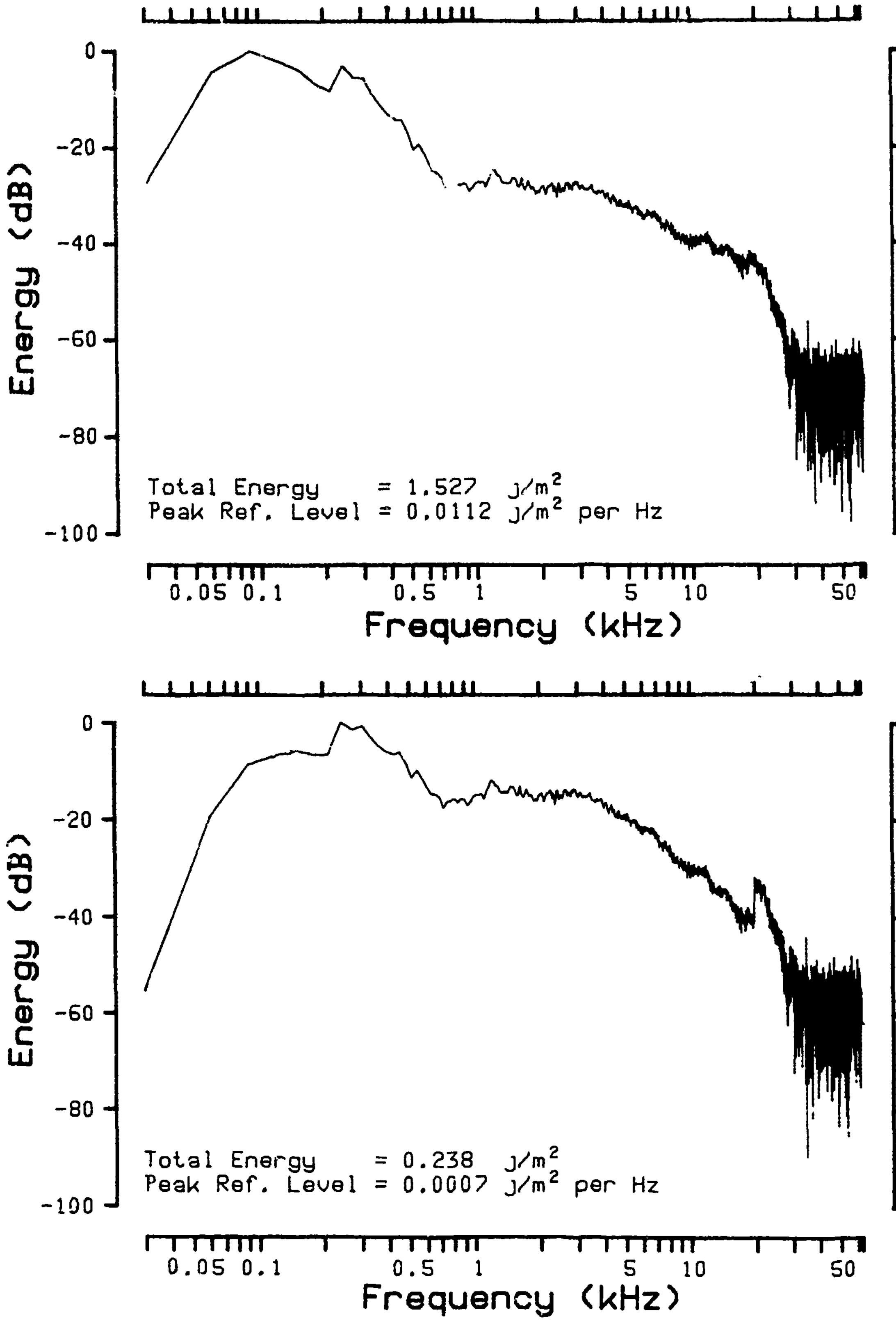


Figure 13. The unweighted (upper) and A-weighted (lower) energy spectra for the 155 dB peak SPL blast wave.

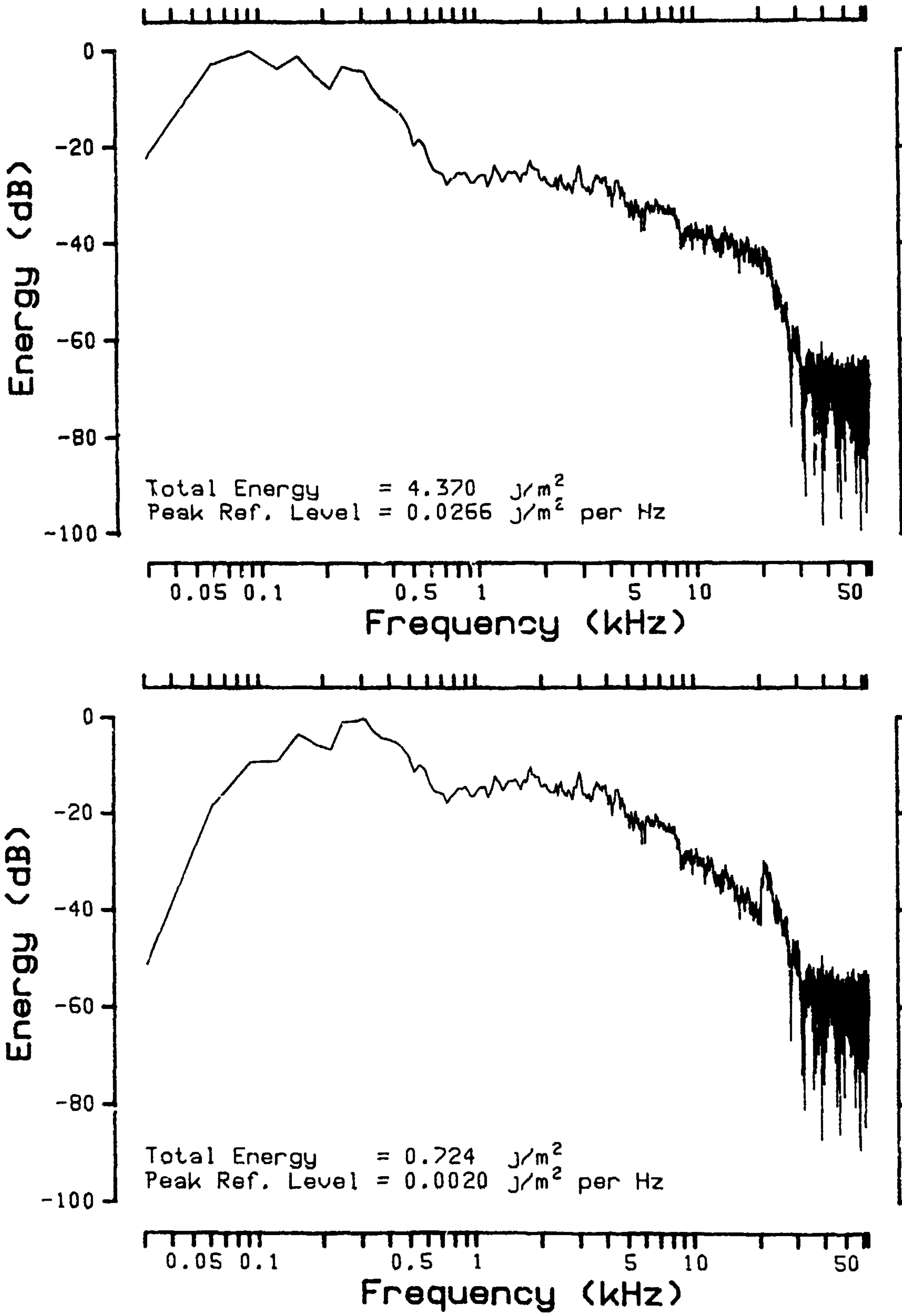


Figure 14. The unweighted (upper) and A-weighted (lower) energy spectra for the 160 dB peak SPL blast wave.

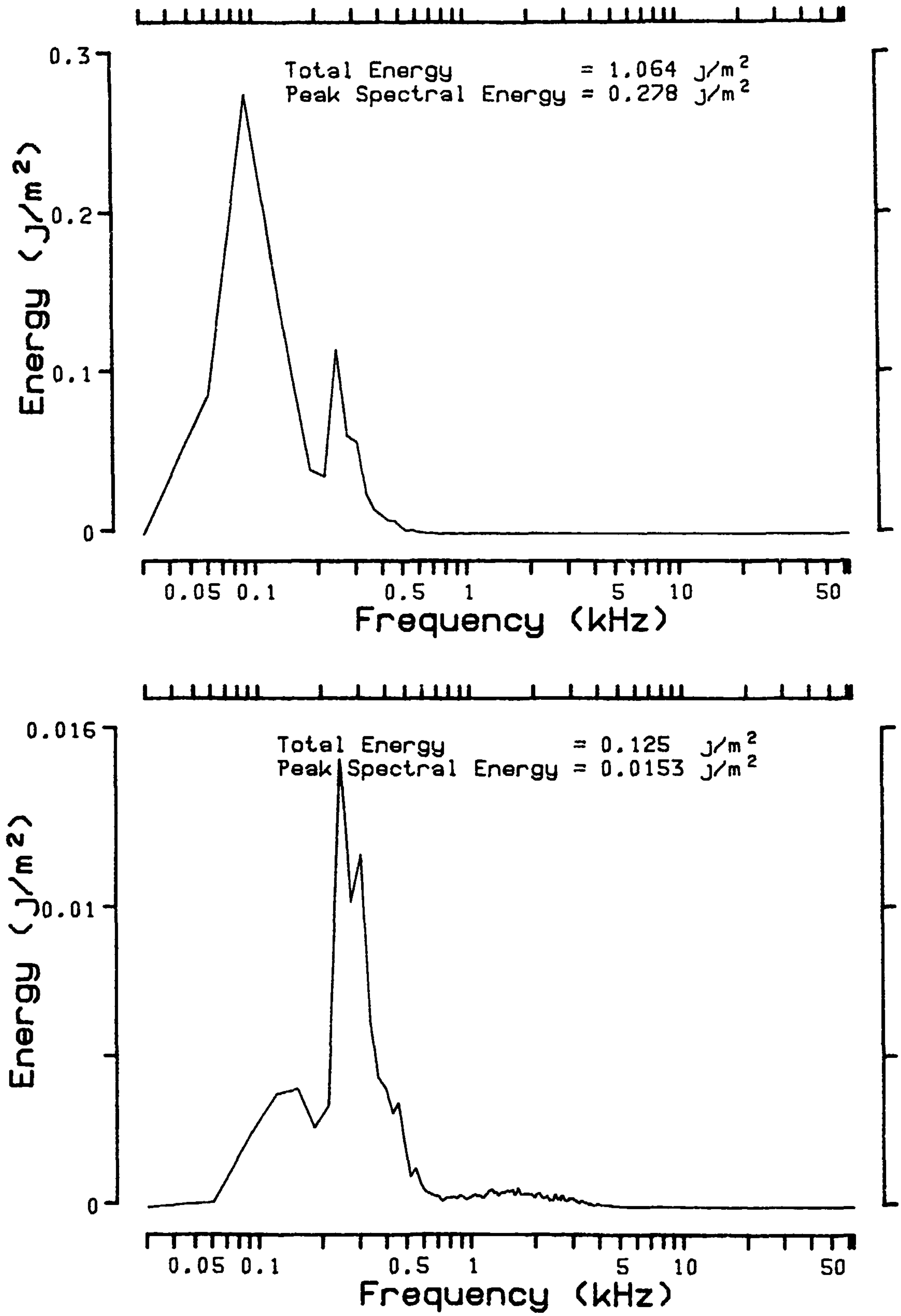


Figure 15. The unweighted (upper) and A-weighted (lower) energy spectra for the 150 dB peak SPL blast wave in absolute units.

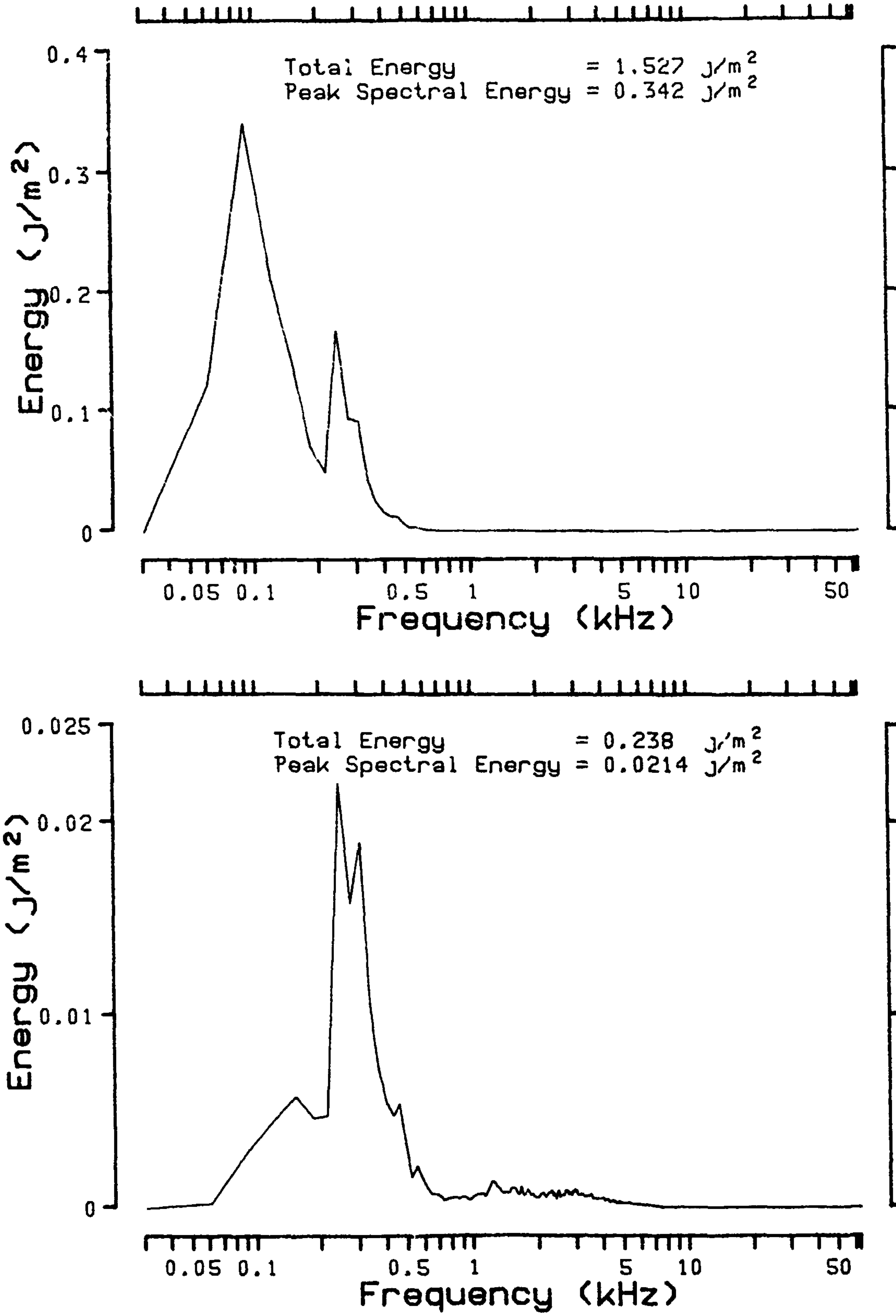


Figure 16. The unweighted (upper) and A-weighted (lower) energy spectra for the 155 dB peak SPL blast wave in absolute units.

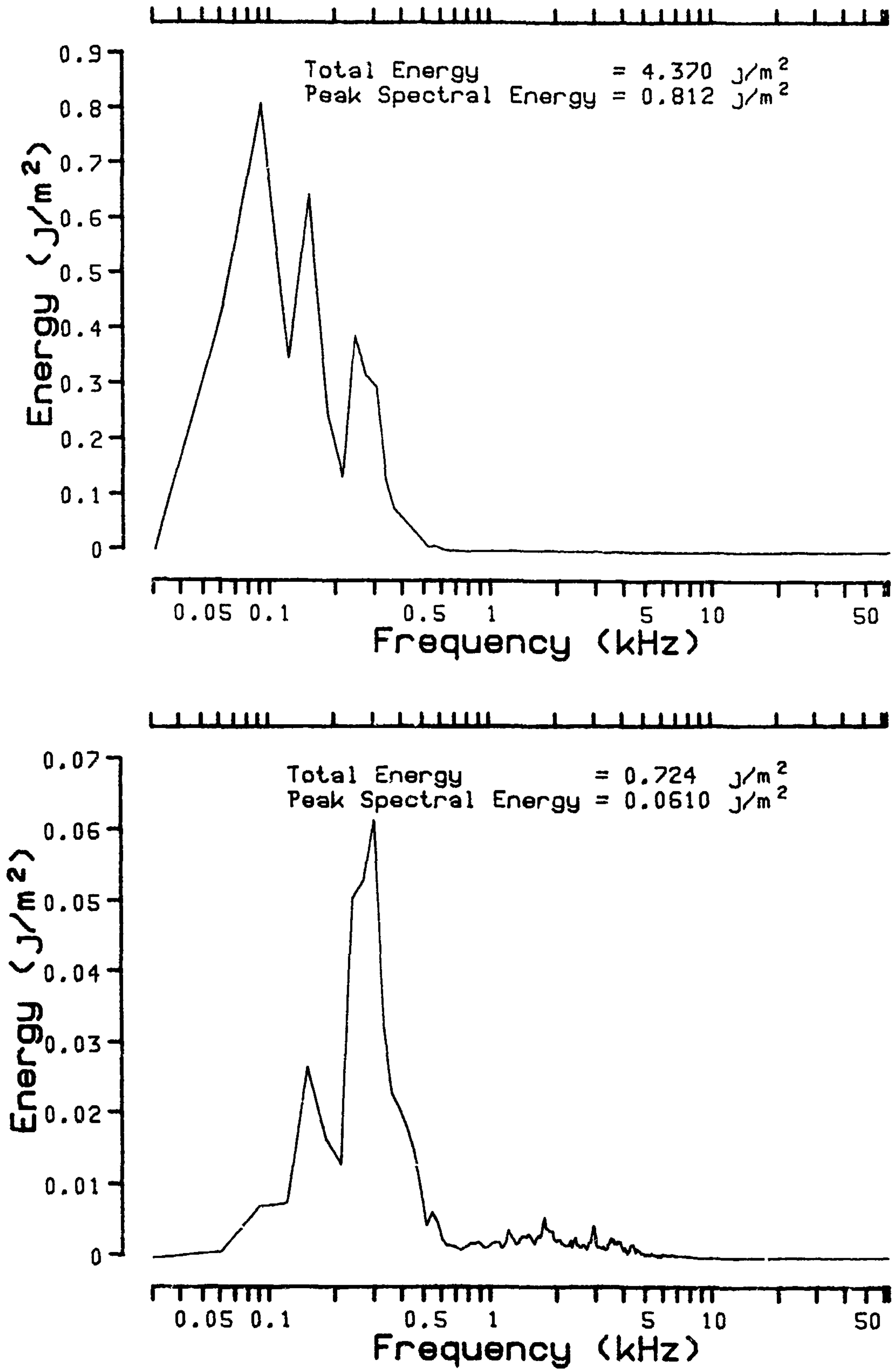


Figure 17. The unweignted (upper) and A-weighted (lower) energy spectra for the 160 dB peak SPL blast wave in absolute units.

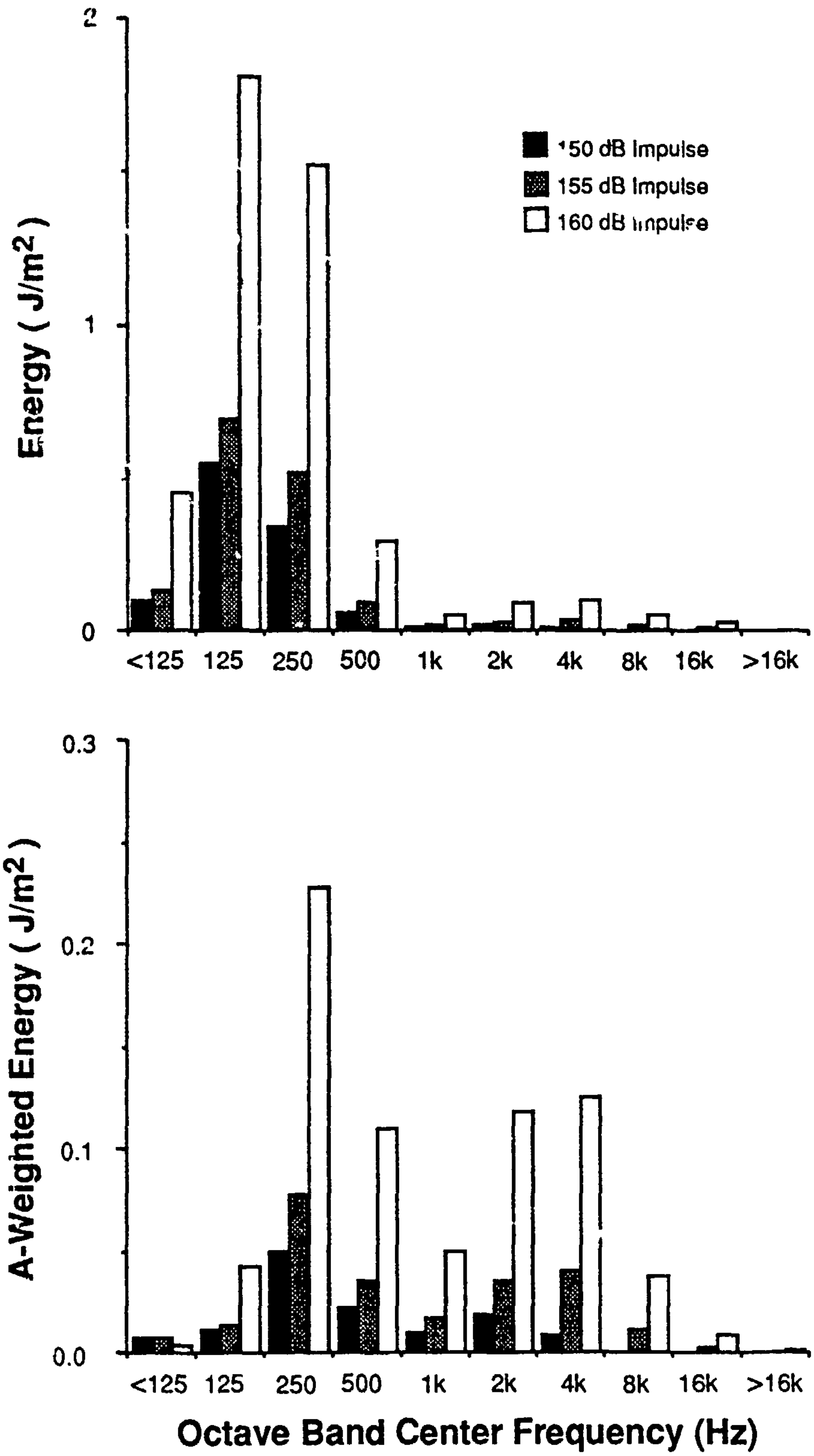


Figure 18. The unweighted (upper) and A-weighted (lower) octave band analysis of the three biast waves, compared in absolute units.

approximately 1.4ms. When the three p-t traces are expanded and overlayed the temporal configuration is essentially identical for each wave form and the waves differ in the peak of the first positive over pressure and somewhat in the peak of the first rarefaction phase of the wave.

The peak of the energy spectrum is in the 0.125 kHz octave band region. At the high frequencies i.e. 2 to 20 kHz the spectrum falls off at the rate of approximately 6 dB/octave for the 160 dB wave and at 7 and 9 dB/octave for the two lower intensity 155 and 150 dB waves respectively. These high frequency slopes were estimated after "eye-fitting" a straight line to the high frequency portion of the spectrum. This more rapid drop off for the two lowest intensity waves probably reflects the increased rise time of the pressure front indicative of a break down in the leading shock front. An increased rise time in the wave form at 150 dB peak SPL is noticeable when the time resolution of the p-t traces is increased.

The total energies both unweighted and A-weighted for each of the wave forms and exposures used are shown in Table III. In all three wave forms the maximum energy is found in the octave band centered at 125 Hz.

<u>Postexposure Audiometric Results</u>: The TS_{max}, PTS and Cell loss data were analyzed using a mixed-model analyses of variance with frequency as a within-subjects factor and peak SPL (150, 155, 160 dB Peak SPL), number (1X, 10X, 100X), and/or rate (10/min, 1/min, 1/10 min) as between-subjects factors. Several analyses were employed. Two-factor analyses of variance (level and frequency) was performed on the data from groups exposed to only one impulse at the three blast intensities. Three-factor analyses of variance (rate, level and frequency) were performed on the groups exposed to 10 blast waves or to 100 blast waves. The probability for a Type I error was set at 0.05 for all analyses.

1. <u>Maximum Threshold Shift</u>: The mean TS_{max} for the three groups exposed to a single blast wave at 150, 155 or 160 dB peak SPL is illustrated in the upper panel of Figure 19. The summary table for the two-factor analysis of variance of TS_{max} for these three groups is presented in Table IV. Although the main effect of frequency was statistically significant, neither the main effect of blast level nor the level by frequency interaction was significant.

The summary table for the three-factor analysis of variance of TS_{max} for the nine 10X groups (three levels crossed with three rates) is presented in Table V. The mean TS_{max} values are illustrated in the upper panels of Figures 20, 22 and 24. The main effects of level and frequency were statistically significant as was the interaction of level and frequency. Thus, as depicted in Figure 24, the 160 dB impulses resulted in significantly more TS_{max} than the other groups (i.e., 150 and 155 dB) and this difference was frequency dependent, occurring at the higher 2.0 and 8.0 kHz test frequencies.

The upper panels in Figures 21, 23 and 25 presents the mean TS_{max} for the nine groups exposed to 100 blasts with an accompanying analysis of variance summary in Table VI. All main effects were statistically significant as well as the interaction between rate and blast level. None of the interactions with the within-subjects factor of frequency reached statistical significance. Thus, both factors of blast level and presentation rate had an effect on the amount of TS_{max} produced by 100 impulses. However, the effect of the blast wave level was dependent upon the rate of presentation. For example, the 150 dB Peak SPL impulse groups are clearly

TABLE IV

Analysis of Variance Summary Table for Maximum Threshold Shift for Groups Exposed to 1 Impulse

Source of Variation	SS	df	MS	F	Sig of F
Level	215.669	2	107.835	1.143	.354
Between Subjects	1037.487	11	94.317		
Frequency	612.968	2	306.484	6.886	.005
Level x Frequency	236.508	4	59.127	1.329	.291
Within Subjects	979.11	22	44.505		

TABLE V

Analysis of Variance Summary Table for Maximum Threshold Shift for Groups Exposed to 10 Impulses

Source of Variation	SS	df	MS	F	Sig of F
Rate	455.649	2	227.825	.172	.843
Level	12023.038	2	6011.519	4.540	.017
Rate x Level	6166.266	4	1541.567	1.164	.343
Between Subjects	47673.619	36	1324.267		
Frequency	3530.907	2	1765.453	24.718	.000
Rate x Frequency	691.750	4	172.938	2.421	.056
Level x Frequency	1600.296	4	400.074	5.601	.001
Rate x Level x Frequency	760.776	8	95.097	1.331	.242
Within Subjects	5142.603	72	71.425		

TABLE VI

Analysis of Variance Summary Table for Maximum Threshold Shift for Groups Exposed to 100 Impulses

Source of Variation	SS	df	MS	F	Sig of F
Rate	7404.763	2	3702.382	4.346	.020
Level	13061.493	2	6530.747	7.666	.002
Rate x Level	15412.222	4	3853.055	4.523	.004
Between Subjects	31522.036	37	851.947		
Frequency	2910.525	2	1455.262	11.323	.000
Rate x Frequency	217.204	4	54.301	.423	.792
Level x Frequency	1084.577	4	271.144	2.110	.088
Rate x Level x Frequency	943.124	8	117.890	.917	.507
Within Subjects	9510.489	74	128.520		

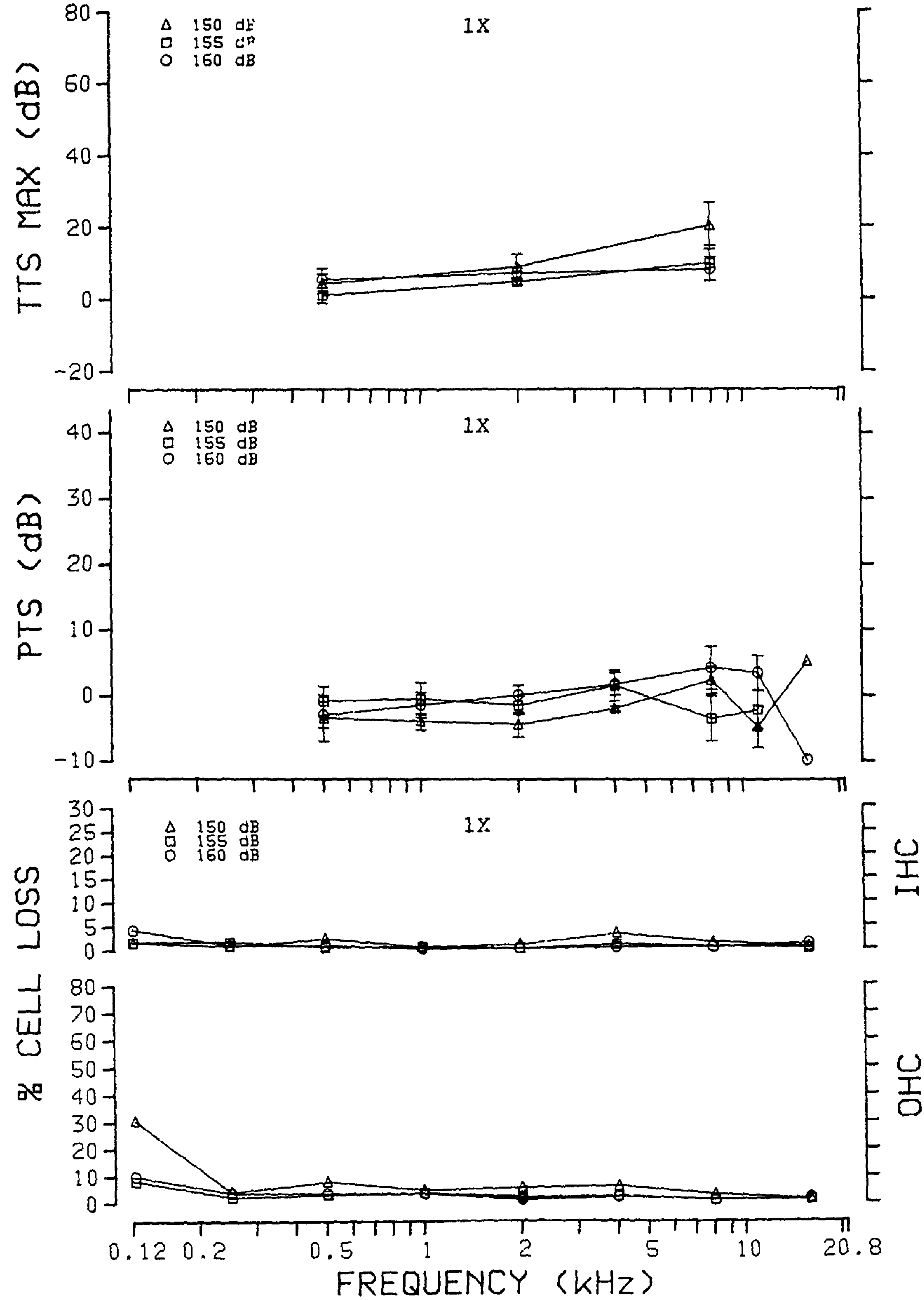


Figure 19. Mean TS_{max} (upper), PTS (middle) and sensory cell loss (lower) for groups of animals exposed to 1 blast wave.

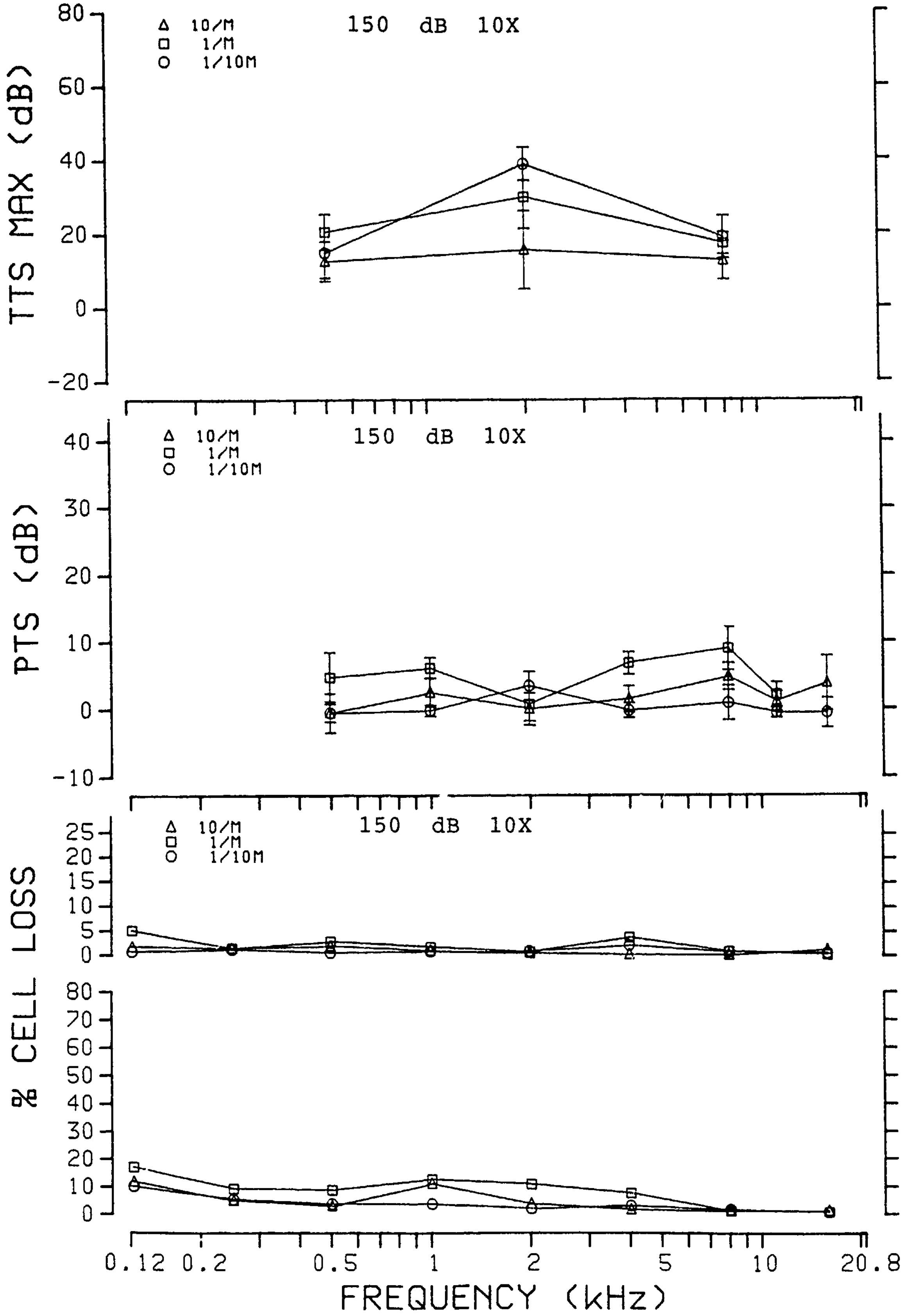


Figure 20. Mean TS_{max} (upper), PTS (middle) and sensory cell loss (lower) for groups of animals exposed to 10 blast waves at 150 dB peak SPL.

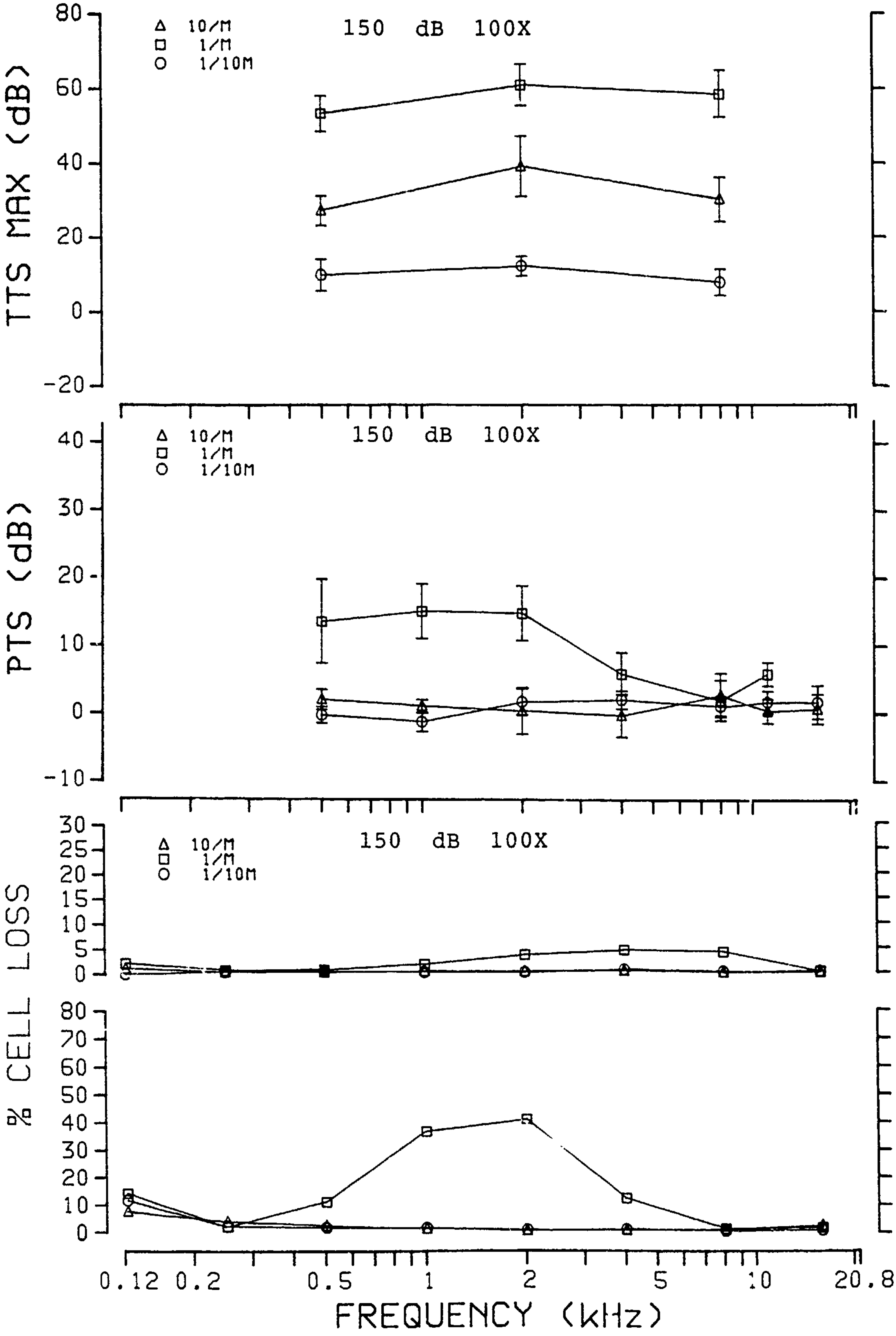


Figure 21. Mean TS_{max} (upper), PTS (middle) and sensory cell loss (lower) for groups of animals exposed to 100 blast waves at 150 dB peak SPL.

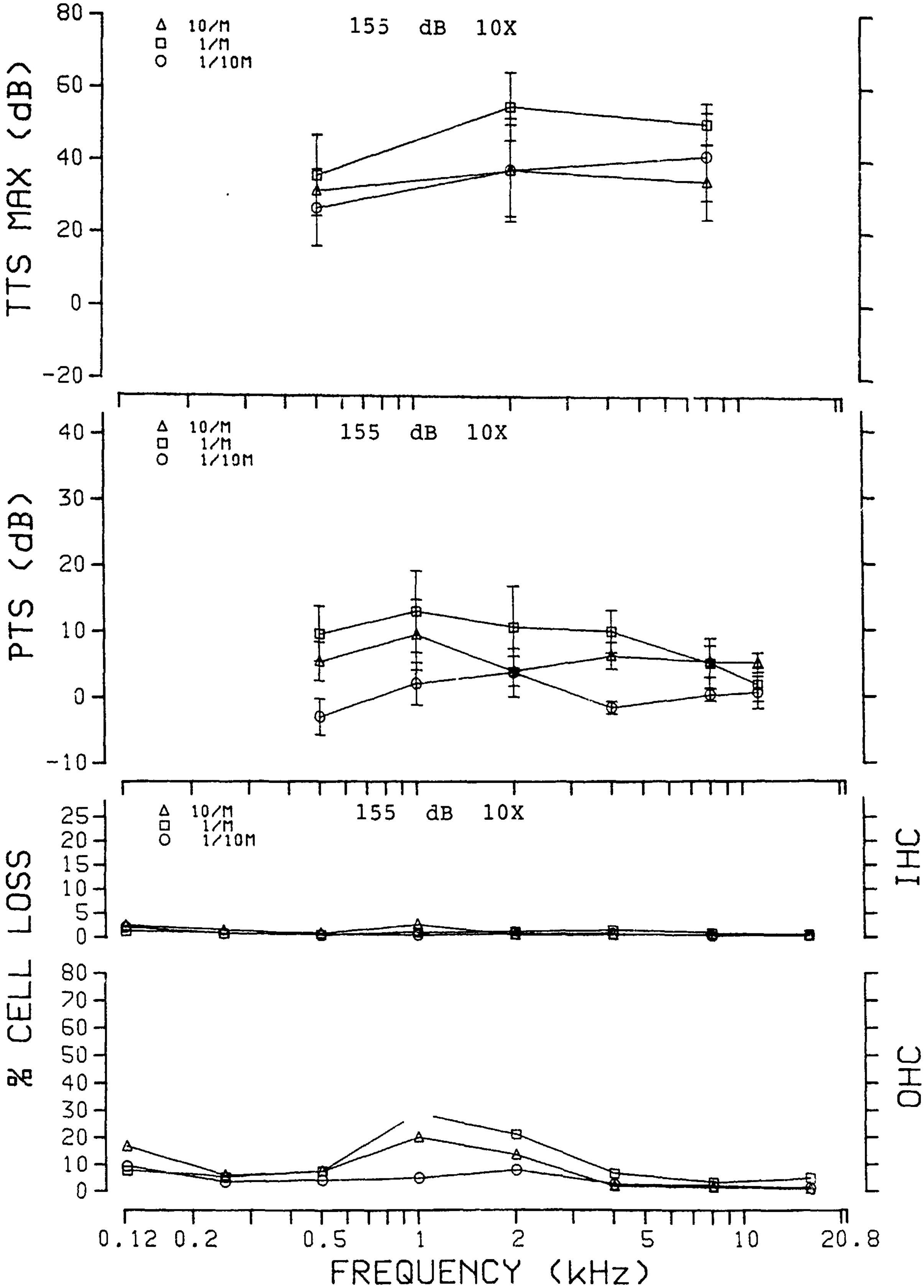


Figure 22. Mean TS_{max} (upper), PTS (middle) and sensory cell loss (lower) for groups of animals exposed to 10 blast waves at 155 dB peak SPL.

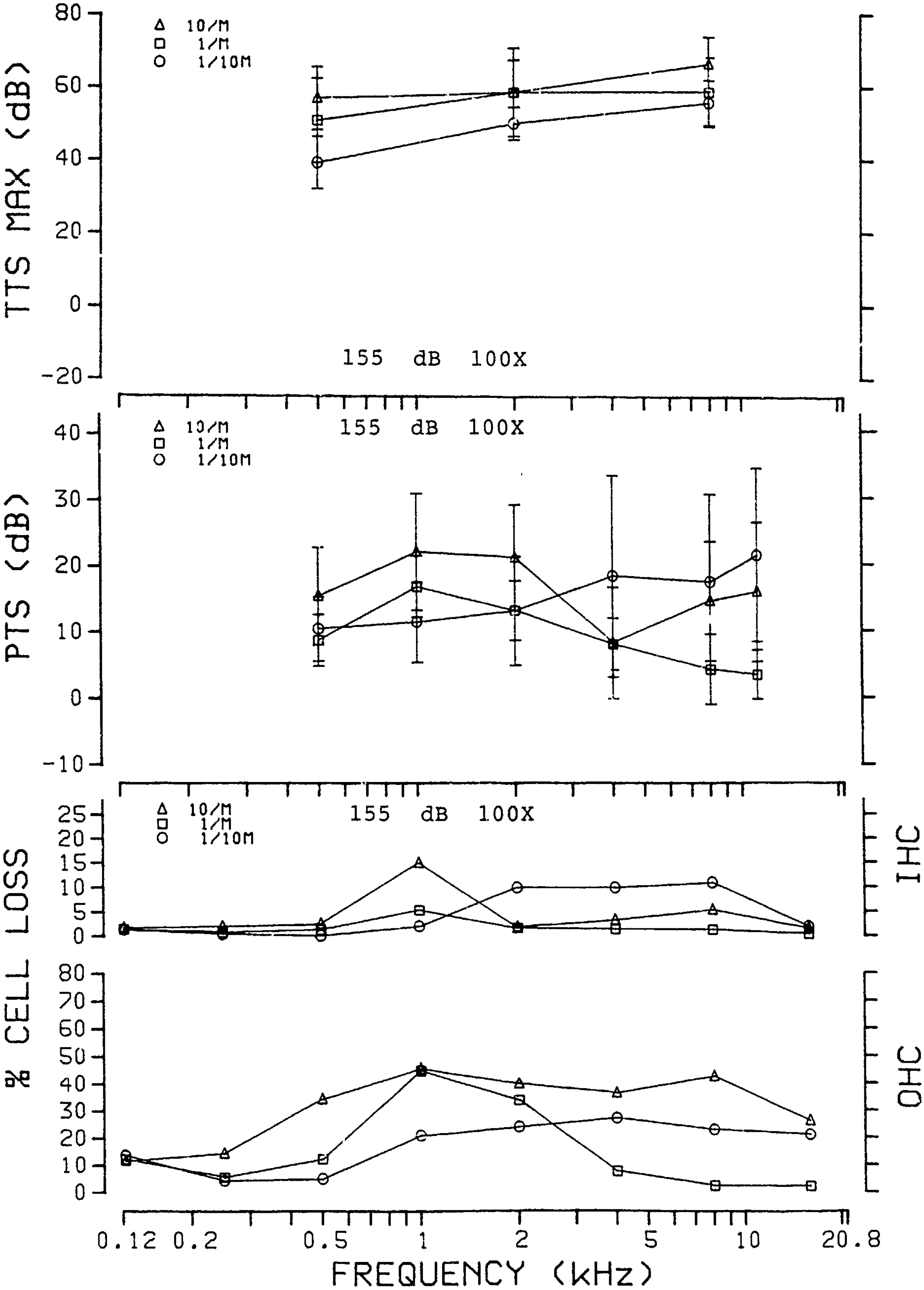


Figure 23. Mean TS_{max} (upper), PTS (middle) and sensory cell loss (lower) for groups of animals exposed to 100 blast waves at 155 dB peak SPL.

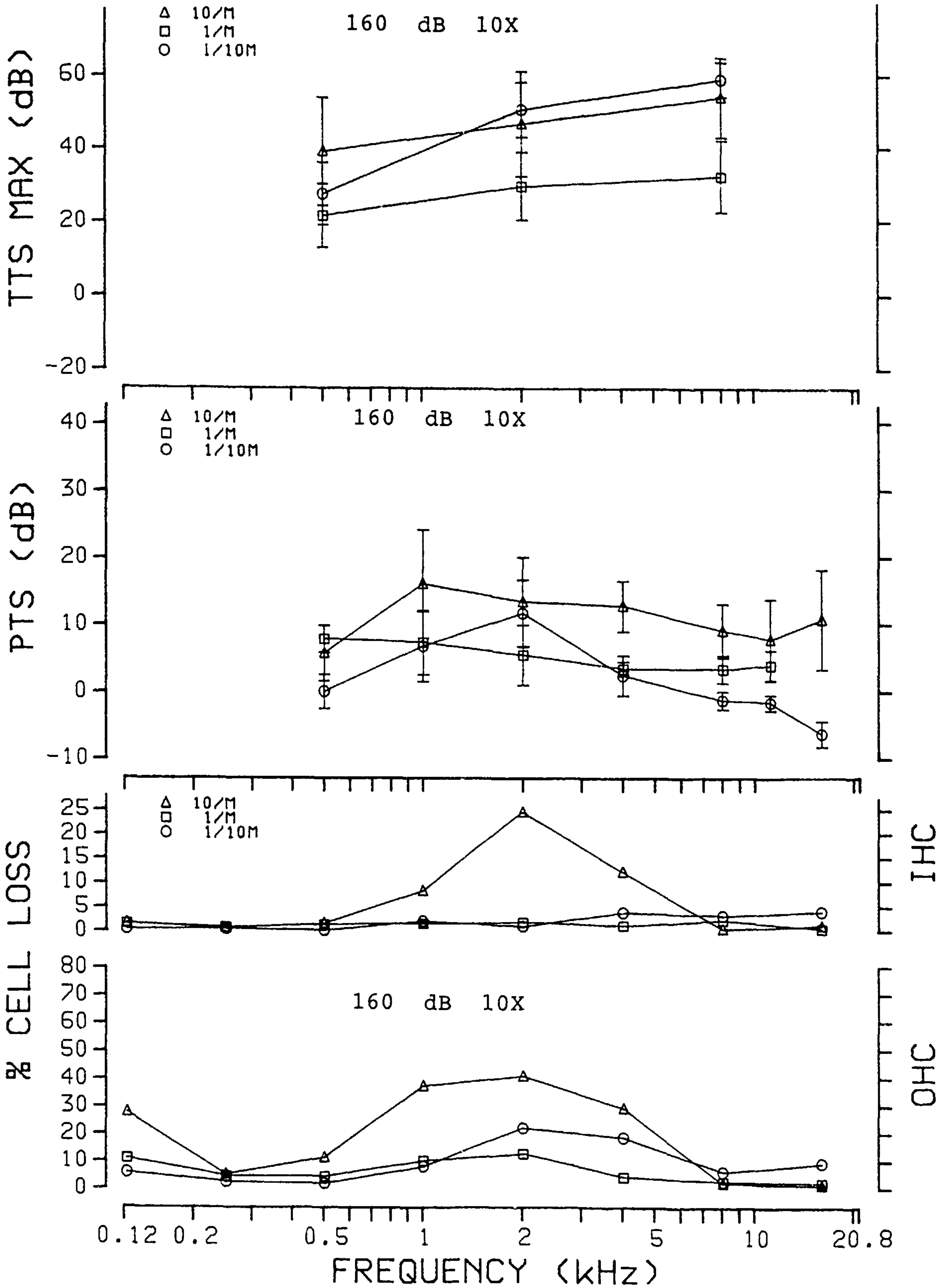


Figure 24. Mean TS_{max} (upper), PTS (middle) and sensory cell loss (lower) for groups of animals exposed to 10 blast waves at 160 dB peak SPL.

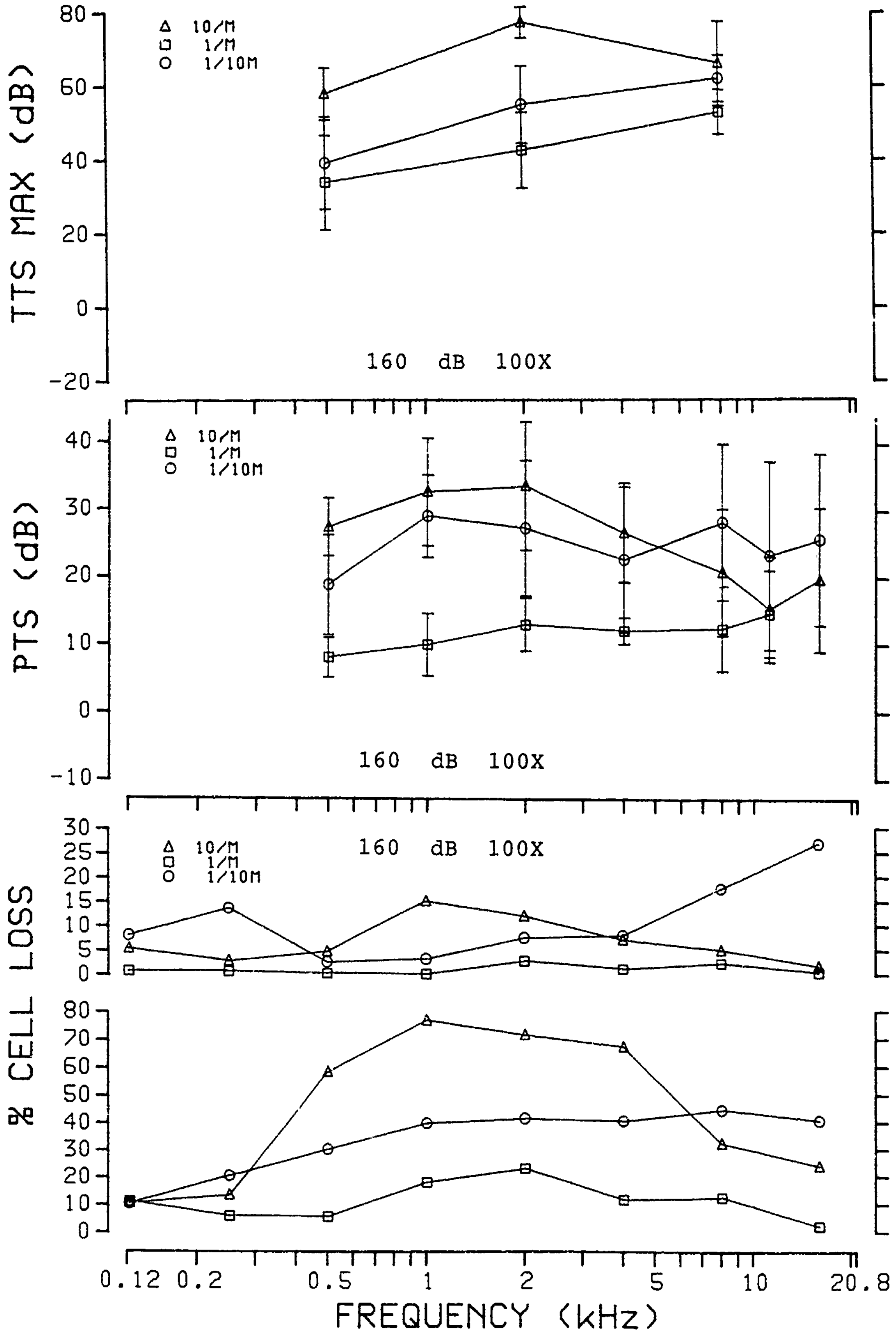


Figure 25. Mean TS_{max} (upper), PTS (middle) and sensory cell loss (lower) for groups of animals exposed to 100 blast waves at 160 dB peak SPL

ordered with the 1/1m group showing the most TS_{max} and the 1/10m showing the least TS_{max}. However, this ordering was not seen for the other two impulse intensity levels. Further, there was more TS_{max} resulting from the 155 and 160 dB Peak SPL impulses for the groups exposed to one impulse per minute, but not at the other two rates. A separate two-factor analysis of variance showed no rate effect for either the 155 or 160 dB Peak SPL impulse groups.

2. Permanent Threshold Shift: The mean PTS levels for the three groups exposed to one impulse only are illustrated in the middle panel of Figure 19. The accompanying analysis of variance table is presented in Table VII. The were no statistically significant differences in mean PTS for these three groups.

The mean PTS levels for the nine groups exposed to 10 impulses are presented in the middle panels of Figures 20, 22 and 24 with the accompanying analysis of variance summary table in Table VIII. The main effects of rate and frequency were statistically significant while the main effect of blast level and all interactions were not significant. An examination of the means collapsed across frequency reveals that the 1/10M produced less PTS than either of the other two rates. Differences in PTS at different frequencies was expected on the basis of the predominantly low frequency energy of the impulse.

The mean PTS levels for the nine groups exposed to 100 impulses are presented in the middle panels of Figures 21, 23 and 25. The summary table for the mixed-model analysis of variance is shown in Table IX. The main effects of blast level and frequency were statistically significant while the main effect of rate and all interactions were not significant. The mean PTS produced by the different blast waves is ordered with the 150 dB Peak SPL blast producing the least PTS and the 160 dB Peak SPL blast producing the most PTS. A statistically significant frequency effect was again observed.

Histological Results: Each animal's cochlea was dissected and prepared for standard surface preparation histology. The dependent variables examined in this report are the inner and outer hair cells grouped in octave-band lengths of the cochlea from .125 to 16.0 kHz to allow comparison with the TS_{max} and PTS results

1. Outer Hair Cell Loss: The mean percent OHC losses for the three groups exposed to one blast wave are illustrated in the lower panel in Figure 19. The analysis of variance summary table for this figure is presented in Table X. The analysis of variance revealed statistically significant main effects of impulse level and frequency and a significant level by frequency interaction. Inspection of the figure reveals that there was very little OHC losses in all groups at all frequencies. Further, given the very small losses in each animal, there was also very little variability within groups. The elevated sensory cell loss within the .125 kHz octave band for the 150 dB 1X group was the main cause of all three statistically significant F ratios. When the .125 kHz OB is excluded from the analysis, only a statistically significant frequency effect is seen.

The lower panel in Figures 20, 22 and 24 illustrate the mean percent OHC losses for the nine groups exposed to 10 impulses. The analysis of variance summary for these figures is presented in Table XI. The three way analysis of variance revealed only a statistically significant frequency effect. The main effects of level and rate and all interactions were not statistically significant.

TABLE VII

Analysis of Variance Summary Table for Permanent Threshold Shift for Groups Exposed to 1 Impulse

Source of Variation	SS	df	MS	F	Sig of F
Level	191.849	2	95.924	1.562	.249
Between Subjects	736.767	12	61.397		
Frequency	147.111	5	29.422	1.330	.264
Level x Frequency	294.708	10	29.471	1.332	.235
Within Subjects	1327.222	60	22.120		

TABLE VIII

Analysis of Variance Summary Table for Permanent Threshold Shift for Groups Exposed to 10 Impulses

Source of Variation	SS	df	MS	F	Sig of F
Rate	1422.145	2	711.073	3.692	.035
Level	782.549	2	391.274	2.031	.146
Rate x Level	923.718	4	230.930	1.199	.328
Between Subjects	7126.796	37	192.616		
Frequency	687.689	5	137.538	4.280	.001
Rate x Frequency	556.181	10	55.618	1.731	.077
Level x Frequency	522.754	10	52.275	1.627	.102
Rate x Level x Frequency	505.990	20	25.300	.787	.727
Within Subjects	5945.349	185	32.137		

TABLE IX

Analysis of Variance Summary Table for Permanent Threshold Shift for Groups Exposed to 100 Impulses

Source of Variation	SS	df	MS	F	Sig of F
Rate	1073.888	2	536.944	.469	.629
Level	13726.965	2	6863.482	5.996	.005
Rate x Level	5670.152	4	1417.538	1.238	.311
Between Subjects	44641.450	39	1144.653		
Frequency	918.325	5	183.665	2.613	.026
Rate x Frequency	1157.019	10	115.702	1.646	.096
Level x Frequency	345.799	10	34.580	.492	.894
Rate x Level x Frequency	2159.556	20	107.978	1.536	.073
Within Subjects	13707.713	195	70.296		

TABLE X

Analysis of Variance Summary Table for Percent Outer Hair Cell Losses for Groups Exposed to 1 Impulse

Source of Variation	SS	df	MS	F	Sig of F
Level	539.597	2	269.799	9.782	.003
Between Subjects	330.987	12	27.582		
Frequency	2327.269	7	332.467	14.700	.000
Level x Frequency	1013.807	14	72.415	3.202	.000
Within Subjects	1899.864	84	22.617		

TABLE XI

Analysis of Variance Summary Table for Percent Outer Hair Cell Losses for Groups Exposed to 10 Impulses

Source of Variation	SS	df	MS	F	Sig of F
Rate	1530.730	2	765.365	1.539	.228
Level	2273.215	2	1136.608	2.285	.116
Rate x Level	3654.723	4	913.681	1.837	.142
Between Subjects	18402.007	37	497.352		
Frequency	9078.755	7	1296.965	7.047	.000
Rate x Frequency	2617.936	14	186.995	1.016	.438
Level x Frequency	3727.751	14	266.268	1.447	.132
Rate x Level x Frequency	3782.519	28	135.090	.734	.835
Within Subjects	47670.651	259	184.057		

TABLE XII

Analysis of Variance Summary Table for Percent Outer Hair Cell Losses for Groups Exposed to 1 Impulse

Source of Variation	SS	df	MS	F	Sig of F
Rate	10081.931	2	5040.966	1.532	.229
Level	33182.481	2	16591.240	5.041	.011
Rate x Level	25096.429	4	6274.107	1.906	.129
Between Subjects	128354.459	39	3291.140		
Frequency	24908.748	7	3558.393	10.424	.000
Rate x Frequency	11948.948	14	853.496	2.500	.002
Level x Frequency	8985.392	14	641.814	1.880	.028
Rate x Level x Frequency	16136.024	28	576.287	1.688	.019
Within Subjects	93189.641	273	341.354		

The mean percent OHC losses for the nine groups exposed to 100 blast waves is presented in the lower panel of Figures 21, 23 and 25, with accompanying analysis of variance summary table in Table XII. The main effects of impulse level and frequency, and all three interactions which included frequency, were statistically significant. The 160 dB impulses caused the most average OHC losses while the 150 dB impulses caused the least. The effect of impulse exposure rate and level depended on the frequency at which the losses were measured. The least amount of sensory cell damage occurred at the lowest frequency (0.125 kHz OB) with the greater amounts appearing in the mid-frequency region of the cochlea. The effect of impulse rate on sensory cell damage varied across frequency and level (as evidenced by the statistically significant three-way interaction). As can be seen in the lower panel of Figures 21, 23 and 25, the 1 impulse per minute group showed the most OHC losses in the 150 dB groups, and the least in the 160 dB groups. Further, the amount of loss was dependent on the frequency (i.e., distance along the cochlea) where the losses were measured.

2. Inner Hair Cell Loss: The percent IHC losses for the groups exposed to one impulse are illustrated in the lower panel of Figure 19, with analysis of variance summary in Table XIII. Similar to the OHC loss data, there was little IHC loss in any of the 1X groups. The main effect of frequency was statistically significant as was the level by frequency interaction. The main effect of impulse level was not statistically significant. Inspection of the Figure 19 shows minimal cell losses and variability of loss within groups, which led to the significant F ratios.

The lower panel of Figures 20, 22 and 24 illustrates the percent IHC losses for the nine groups exposed to 10 impulses. Table XIV presents the analysis of variance summary for these groups. The only statistically significant F ratio represented a difference in the effect of impulse level. The mean IHC losses for the 160 dB groups were appreciably higher than for the other two impulse intensities.

The percent IHC loss for the nine groups exposed to 100 impulses is presented in the lower panel of Figures 21, 23 and 25, with accompanying analysis of variance summary in Table XV. The analysis of variance revealed only a statistically significant rate by frequency interaction. All other interactions and main effects were not statistically significant. The figure shows an irregular effect of impulse presentation rate on IHC losses as was the case with the percent OHC losses.

3. Total Hair Cell Loss: There are several alternative methods of analyzing these data, e.g., as a function of total energy of exposure; or by analyzing individual octave bands for interrelations among the physical acoustic variables, audiometric variables and sensory cell loss. These alternate methods are being pursued. One of these alternate approaches is illustrated in Figure 26. The total outer hair cell loss throughout the entire cochlea is related to the total energy of exposure. Also, the mean PTS averaged over the 1.0, 2.0 and 4.0 kHz test frequencies is shown as a function of the total energy of the exposure. These figures visually convey some of the results that were derived from the preceding statistical analysis. The following preliminary conclusions (not in complete agreement with the previously presented statistics) can be made from these data. (1) There was no difference in the amount of hearing loss or the amount of sensory cell loss for exposure to a single impulse at 150, 155 or 160 dB peak SPL. Individual animals showed no permanent hearing loss and no substantial sensory cell loss. (2) There is a considerable increase in the variability or degree of susceptibility across animals as the severity of the exposure increases. This increase in susceptibility seems to be tied more to peak levels of the

TABLE XIII

Analysis of Variance Summary Table for Percent Inner Hair Cell Losses for Groups Exposed to 1 Impulse

Source of Variation	SS	df	MS	F	Sig of F
Level	6.354	2	3.177	1.676	.228
Between Subjects	22.746	12	1.896		
Frequency	42.555	7	6.079	5.071	.000
Level x Frequency	48.321	14	3.452	2.879	.001
Within Subjects	100.695	84	1.199		

TABLE XIV

Analysis of Variance Summary Table for Percent Inner Hair Cell Losses for Groups Exposed to 10 Impulses

Source of Variation	SS	df	MS	F	Sig of F
Rate	360.549	2	180.275	2.032	.145
Level	583.577	2	291.789	3.289	.048
Rate x Level	837.668	4	209.417	2.360	.071
Between Subjects	3282.603	37	88.719		
Frequency	573.314	7	81.902	1.446	.187
Rate x Frequency	912.508	14	65.179	1.151	.314
Level x Frequency	1199.648	14	85.689	1.513	.106
Rate x Level x Frequency	2249.885	28	80.353	1.419	.085
Within Subjects	14670.707	259	56.644		

TABLE XV

Analysis of Variance Summary Table for Percent Inner Hair Cell Losses for Groups Exposed to 100 Impulses

Source of Variation	SS	df	MS	F	Sig of F
Rate	1451.866	2	725.933	1.903	.163
Level	2308.155	2	1154.078	3.026	.060
Rate x Level	2181.601	4	545.400	1.430	.242
Between Subjects	14873.475	39	381.371		
Frequency	1008.995	7	144.142	1.410	.201
Rate x Frequency	2543.166	14	181.655	1.777	.042
Level x Frequency	1038.347	14	74.168	.725	.748
Rate x Level x Frequency	3073.691	28	109.775	1.074	.370
Within Subjects	27908.787	273	102.230		

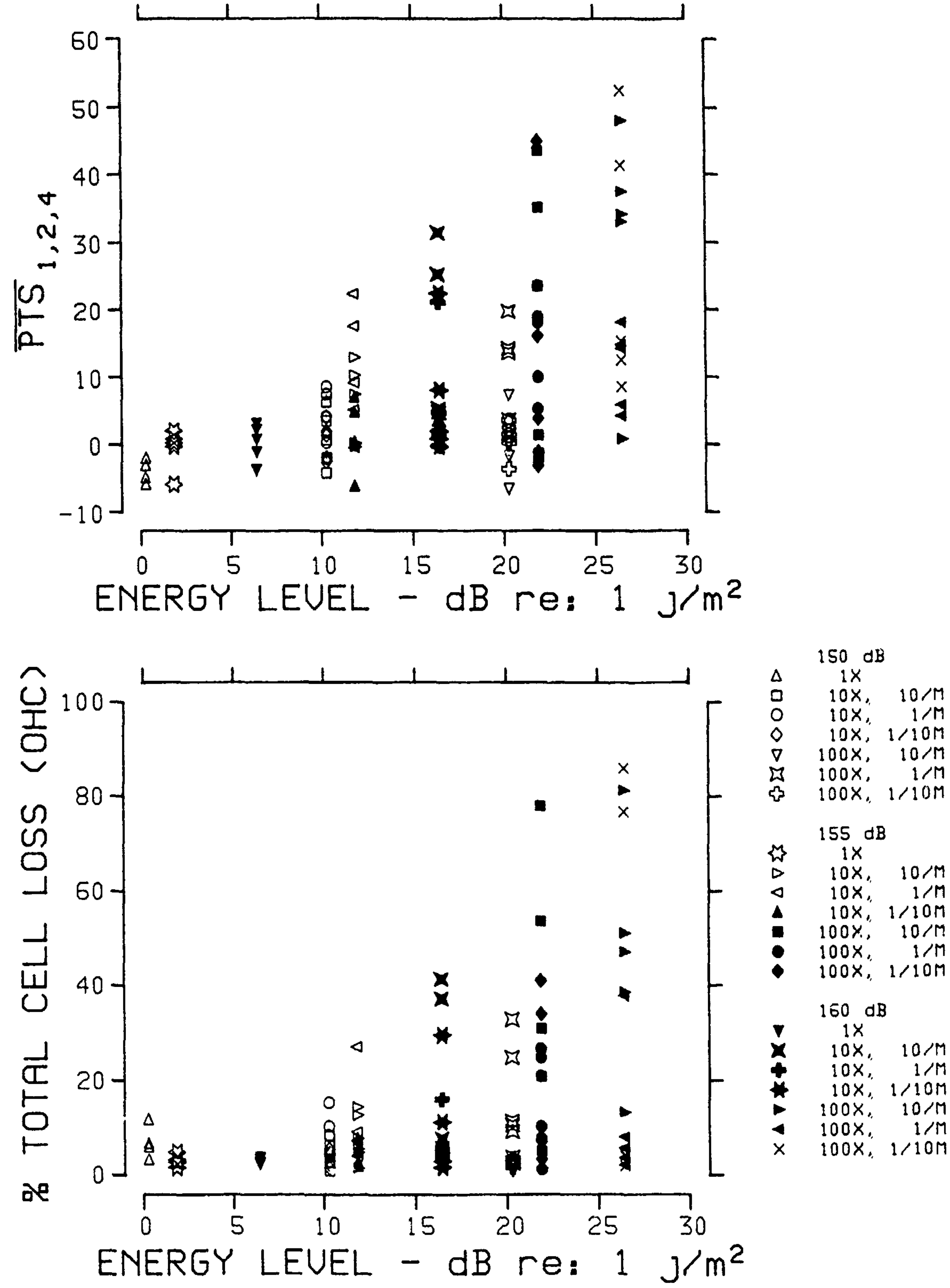


Figure 26. The distribution of permanent effects (audiometric - upper; histological - lower) recorded from individual animals (n=109) for all exposure conditions.

stimulus than it is to the total energy. The variability produces, in the extreme cases, a complete dichotomy in the results (e.g. see the 160 dB, 100x, 1/10m data) that makes it difficult to describe the data with conventional statistics. The only alternative seems to be to substantially increase the total number of animals in such exposure conditions. (3) With the above in mind a general, though not surprising trend in the data is that as the peak levels increase permanent effects increase; these permanent effects seem to be dependent upon peak levels more than upon the total energy in the exposure stimulus. Also, for a constant peak and energy level, the more rapid presentation rate (10/min) produces the greater effect.

Impedance Measurments: Impedance values for individual animals did not reveal any occurrence of tympanic membrane perforation or complete disarticulation of the ossicular chain. Thus, severe middle ear problems probably did not contribute to the variability observed in the postexposure data (Eames, 1975). However, the peak SPL values used in these studies were specifically chosen to be below the level which is known to cause such a pathology.

Table XVI presents the mean preexposure and postexposure impedance results for the two probe frequencies at each of the peak SPL levels used. The effects of noise exposure conditions did result in an overall statistically significant decrease in acoustic impedance (Za) at the 220 Hz probe frequency ($t = 3.19$; $df = 63$) but not at the 660 Hz frequency ($t = 1.66$; $df = 24$). As seen in Table XVI, the statistically significant effect for the 220 Hz probe frequency was principally the result of the 155 dB peak SPL exposure conditions.

Following exposure, 39 of 62 (63%) and 16 of 25 (64%) animals tested showed a decrease in Za (i.e. increased compliancy) at 220 and 660 Hz, respectively. The mean equivalent compliance of the middle ear expressed in cubic centimeters (cc) was 1.7 and 3.1 before exposure and 1.9 and 3.3 after exposure for the 220 and 660 Hz probe tones respectively. This increase also indicates that the middle ear system became, on the average, somewhat more compliant for approximately two thirds of the animals. These data suggest that the effects of our high level noise exposures may leave the middle ear system in a condition that is somewhat mechanically different from the normal ear for an undetermined period of time. Figure 27 shows the distribution of the measured Za values before and after exposure at the two probe frequencies. As indicated in the statistics, the primary effect was a general decrease in Za for the 155 dB exposure conditions. The 160 dB conditions which produced the most audiometric and histological variability show no significant changes in Za.

Table XVI

Mean Preexposure and Postexposure Impedance Measures

Probe Hz \ Intensity	150 dB	155 dB	160 dB	All Subjects	
220 Hz Preexposure	554.75	506.72	521.51	523.76	$\overline{X}$
	126.85	95.99	117.81	112.11	s
	15	24	25	64	N
220 Hz Postexposure	513.27	417.61	504.51	473.97	$\overline{X}$
	103.80	78.53	146.64	121.59	s
	15	24	25	64	N
	1.49	4.47*	0.57	3.19*	t
	14	23	24	63	df
660 Hz Preexposure	112.35		98.30	104.48	$\overline{X}$
	26.01		45.79	38.32	s
	11		14	25	N
660 Hz Postexposure	104.48		86.07	94.17	$\overline{X}$
	25.87		27.04	27.60	s
	11		14	25	N
	1.04		1.27	1.66	t
	10		13	24	df

* $p < 0.05$

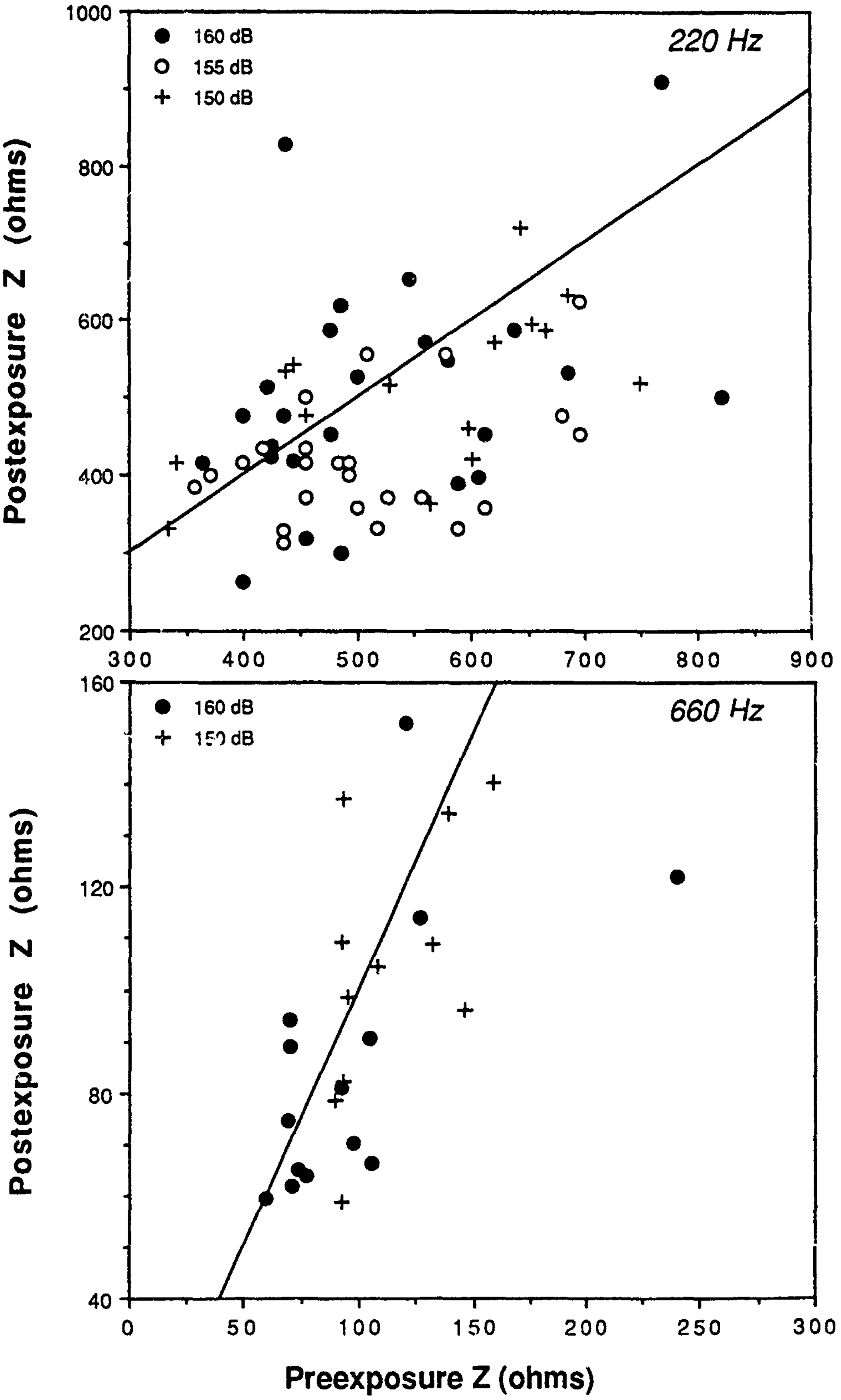


Figure 27. Preexposure and postexposure scatter plot for 220 Hz (upper) and 660 Hz (lower) impedance results.

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